



**COLLEGE OF AGRICULTURE AND RURAL TRANSFORMATION**  
**DEPARTMENT OF PLANT SCIENCE**

**STUDIES ON THE ASSESSMENT OF POST-HARVEST LOSSES OF  
RICE (*Oryza sativa*) IN FOGERA DISTRICT OF AMHARA REGION,  
ETHIOPIA**

**M.Sc. Thesis Research Work**

**By**

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**June 2017**

**Gondar, Ethiopia**



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**By**

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**June 2017**

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## APPROVAL SHEET

### UNIVERSITY OF GONDAR POSTGRADUATE DIRECTORATE

As thesis research advisor, I hereby certify that I have read and evaluated this thesis prepared under my guidance by **Abdella Muhammed** entitled “**Studies on the Assessment of Post-harvest Losses of Rice (*Oryza sativa*) in Fogera District of Amhara Region, Ethiopia**”. I recommend that it be submitted as partial fulfilling for the award of (M.Sc. degree in Agronomy).

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## **ABBREVIATIONS AND ACRONYMS**

ADM	Archer Daniels Midland
APHLIS	Africa Post-harvest Loss Information System
ARBoARD	Amhara Regional Bureau of Agriculture and Rural Development
BC	Before Christ
BCE	Before Common Era
CCAFS	Climate Change, Agriculture and Food Security
CE	Common Era
CGIAR	Consultative Group for International Agricultural Research
CRP	CGIAR Research Program
CSA	Central Statistics Agency
ESA	East and Southern Africa
EUCORD	European Union Cooperation of Rural Development
FAO	Food and Agriculture Organization of the United Nations
Gha	Global Hectar
GIS	Geographic Information System
HL	Harvesting Loss
HH	House Hold
IND	Inland Niger River delta
IRRI	International Rice Research Institute
MC	Moisture Content
NERICA	New Rice for Africa
NRRDSE	National Rice Research and Development Strategy of Ethiopia
PH	Post-Harvest
PHL	Post-Harvest Loss
PICS	Purdue Improved Grain Storage
PP	Poly Propylene
UN	United Nations

## **ABBREVIATIONS AND ACRONYMS (continued)**

URRAP	Universal Rural Road Access Programme
WARDA	West Africa Rice Development Association
Wb	Wet bulb
WFLO	World Food Logistics Organization



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# **Studies on the Assessment of Post-harvest Losses of Rice (*oryza sativa*) in Fogera District of Amhara Region, Ethiopia**

## **ABSTRACT**

*Rice (Oryza sativa) is the most widely cultivated cereal in the world after wheat and produced in a wide range of locations under a variety of climatic conditions. It is source of calorie for almost half of the world's population. It is know that one-third of all food produced for human consumption worldwide is lost. Ethiopia's vast arable land and favorable agro-climatic conditions has a potential of 30,501,524 ha suitable land. This research was conducted in Fogera district of South Gondar Administration Zone of Amhara region, Ethiopia in the main season of 2016. The main objective of the study was to determine the post-harvest loss of rice from harvesting to milling. The study was conducted in two phases; house hold survey and field survey via 'tile plot of block' method for harvesting, threshing, cleaning and drying, milling and experiment for storage loss using three storage material. The study Kebele (peasant association) was selected using purposive sampling technique and the 70-farm household selected randomly. Primary data pertaining to 2016 cropping season collected from sample respondents using a semi-structured questionnaire and sample field data were recorded on practical basis. Focus group discussion and key informant interview was also conducted. Statistical Package for Social Science (SPSS) version 20.0 (2011) was employed to analyze the data for the collected data and the analyzed data presented using tables and figures. Based on the results of this survey farmers awareness of losses due to post-harvest loss but believed that it is natural and they do nothing to reduce it. The local storage (Gotta/Gottera) and polypropylene bags are the available storage materials where 98.6% of the respondents indicated that PP bag has the highest loss. Milling was one of the significantly addressed issue as the major PHL source where 94.3% of the respondents outlined. In the study area farmers use two-pass milling machine for home consumption and one-pass for market purpose. Based on the field survey finding, a mean loss of 3.04% for harvesting, 3.84% for threshing, 1.11% for cleaning and drying, 2.4% for storage and 5.87% for milling was recorded. On the other hand, the milling recovery of 67.86%, 76.8% and 80.13% were measured for white, brown and parboiled rice respectively. The performance of two millers shown 1.73% difference and the head rice yield of 49.15%, 95.9% and 97.8% recorded for white, brown and parboiled rice. Generally, a mean loss of 16.06%, that ranging **10.29 to 27.06%** was recorded and farmers are aware of it. Parboiling and two-pass milling machine has high milling yield and PICS bag has high milling advantage and zero loss record. Improvement in PH extension, introduction of small scale PH technologies, promotion of PICS bag and further PH studies are recommended.*

**Key words:** harvesting, threshing, storage, milling, parboiled.

## **CHAPTER: 1**

### **1. INTRODUCTION**

#### **1.1 Background of Rice Production**

Rice (*Oriza spp*) is after wheat, the most widely cultivated cereal in the world and it is the most important food crop for almost half of the world's population (IRRI, 2009). Rice production in 2014 globally reached 750 million tonnes of paddy of which Africa accounts 27 million tonnes (FAO, 2014). Since 2006, Ethiopian rice production trends show increases in both area and productivity. The country has 17 million hectares of land suitable to rice production. During the Third General Meeting run by the Coalition for African Rice Development (CARD), the Ethiopian government recognized that rice significantly contribute to improving food security and poverty reduction. The introduction and expansion of rice production in suitable agro-ecologies could be an option to achieve food security and self-sufficiency. Even though rice is not a traditional staple food in Ethiopia, it is considered a high potential emergency and food security crop, labelled as “millennium crop” (EUCORD, 2012).

#### **1.2 Post-harvest Loss of Rice**

The post-harvest system consists of a set of operations that cover the period from harvest to consumption. An efficient post-harvest system aims to minimize losses and maintain the quality of the crop until it reaches the final consumer. When food losses are minimized, both food security and income increase, (Grolleaud, 2001). The study on post-harvest losses in food grains at different stages of their handling would help assess the extent and magnitude of losses and identify the factors responsible for such losses. This in turn would help develop proper measures to reduce these losses. Evolving correct policies for minimizing post-harvest losses would crucially depend on reliable and objective estimates of such losses at different stages. This information is important for scientists, technologists, policymakers, administrators and industrialists (Basavaraja *et al.*, 2007).

#### **1.3 Major Causes of Post-harvest Losses in Rice Production**

The causes of post-harvest losses, which some estimates suggest could range from 15 to as high as 50 percent of what is produced. Post-harvest losses can occur during any of the various

stages of post-production system (Taiwo A. and Bart-Plange A., 2016). The main causes of rice losses in post-harvest operations include: delayed harvesting and threshing, heavy dependence on traditional threshing practices, heavy rainfall during harvesting and drying seasons, lack of mechanical drying facilities, over-boiling or under-boiling instead of steaming the paddy in parboiling, high broken percentage in hulling and polishing, lack of proper technical knowledge. Post-harvest losses result from spillage, inefficient retrieval, inefficient processing of rice as well as inadequate machinery, poor operator skills, biological deterioration and infestation by storage pest. Poor transport conditions or defective packaging of grain can lead to quantitative packaging of grain leading to quantitative losses of product (FAO, 2008).

### **1.3.1 Present major rice-growing areas**

Rice is produced in a wide range of locations and under a variety of climatic conditions, from the wettest areas in the world to the driest deserts. It is produced along Myanmar's Arakan Coast, where the growing season records an average of more than 5,100 mm of rainfall, and at AlHasa Oasis in Saudi Arabia, where annual rainfall is less than 100 mm. Temperatures, too, vary greatly. In the Upper Sind in Pakistan, the rice season averages 33 °C; in Otaru, Japan, the mean temperature for the growing season is 17 °C. The crop is produced at sea level on coastal plains and in delta regions throughout Asia, and to a height of 2,600 m on the slopes of Nepal's mountains. Rice is also grown under an extremely broad range of solar radiation, ranging from 25% of potential during the main rice season in portions of Myanmar, Thailand, and India's Assam State to approximately 95% of potential in southern Egypt and Sudan (CGIAR, 2013 b).

### **1.3.2 Genetic diversity of rice**

Two rice species are important cereals for human nutrition: *Oryza sativa*, grown worldwide, and *Oryza. glaberrima*, grown in parts of West Africa. These two cultigens-species known only by cultivated plants belong to a genus that includes about 25 other species, although the taxonomy is still a matter of research and debate (CGIAR, 2013 b).



Among the wild relatives of *O. sativa*, the perennial *O. rufipogon* is widely distributed over South and Southeast Asia, South eastern China, and Oceania. The morphologically similar *O. glumaepatula* is found in South America, usually in deep-water swamps. A closely related annual wild form, *O. nivara*, is found in the Deccan Plateau and Indo-Gangetic Plains of India and in many parts of Southeast Asia. The habitats of *O. nivara* are ditches, water holes, and edges of ponds. Morphologically similar to (and sometimes indistinguishable from) *O. nivara* are the very widely distributed weedy forms of *O. sativa*, which represent numerous different hybrids between *O. sativa* and its two wild relatives. Throughout South and Southeast Asia, these spontaneous hybrids are found in canals and ponds adjacent to rice fields and in the rice fields themselves (CGIAR, 2013 b).

The primary center of diversity for *O. glaberrima* is in the swampy basin of the upper Niger River. Two secondary centers are located in the southwest near the Guinean coast. *O. glaberrima* varieties can be divided into two ecotypes: deep-water and upland. In West Africa, *O. glaberrima* is a dominant crop grown in the flooded areas of the Niger and Sokoto River basins (CGIAR, 2013 b).

### **1.3.3 Rice as human food**

Rice, wheat, and maize are the three leading food crops in the world; together they directly supply more than 42% of all calories consumed by the entire human population. Wheat is the leader in area harvested each year with 225 million hectares (ha) in 2009, followed by maize and rice, both with 159 million ha. Human consumption in 2009 accounted for 78% of total production for rice, compared with 64% for wheat and 14% for maize (CGIAR, 2013 b).

Of the three major crops, rice is by far the most important in terms of human consumption in low- and lower-middle income countries for almost half of the world's population (IRRI, 2009). Maize has always been primarily a feed crop for animals-feed use and historically accounted for about two-thirds of total consumption. This proportion has declined slightly in recent years to about 60% (CGIAR, 2013 b). It is estimated that rice sustains the livelihood of 100 million people and its production has employed more than 20 million farmers in Africa (WARDA, 2005). Sub-Saharan Africa accounts for more than 30% of the worlds rice import with an import bill of more than US\$ 2 billion per year, the reasons for that being urbanization

and population growth (FAO, 2008). Over 90% of the world's total rice crop is produced in South and East Asia. In area and production, China is the leading country in the world.

Africa accounts for 3% of global production. The major limiting factor for the growth of rice is not climate, but water supply. Rice is the only major crop that can be grown in the standing water in vast areas of flat, low-lying tropical soils and is uniquely adapted for growth in submerged conditions. Rice is grown in the tropical and subtropical regions of most continents. It is cultivated under widely differing conditions because of the great cultivar diversity (EUCORD, 2012).

#### **1.4 Challenges in the Battle of Improving Food Security and Loss Reduction**

Tackling food loss and waste could make a significant contribution to combating hunger and increasing farm incomes where it is needed most. One-third of all food produced for human consumption worldwide is lost or wasted. That translates into 1.3 billion tonnes, worth nearly one trillion US dollars. The quantity of food thrown out in industrialized countries is the same as the entire amount produced in sub-Saharan Africa (FAO, 2011).

Food losses occur at all stages of the supply chain, but the causes and impacts vary between North and South. In developing countries, it is estimated that nearly 65% of losses occur at the production, processing and post-harvest stages. In industrialized countries, food waste often occurs at the consumer end of the supply chain (CTA, 2012). Food loss and waste accounts for roughly US\$680 billion in industrialized countries and US\$310 billion in developing countries. Recent studies commissioned by FAO estimate annual food losses and waste at about 30% for cereals, 40 to 50% for root crops, 30% for fish and 20% for oilseeds and meat and dairy products. On a global scale, just 43% of the fruits and vegetables produced is consumed. The remaining 57% is wasted (CTA, 2012). Much of the food loss and waste is avoidable, although the causes may differ widely. In developing countries, more than 40% of food losses occur at post-harvest and processing levels, while in industrialized countries, more than 40% of losses occur at the retail and consumer stages. Saving even one-quarter of the food currently lost or wasted would be enough to feed 900 million people in the world, according to FAO (2011).

## 1.5 Statement of the Problem

Food and Agriculture Organization of United Nations predicts that about 1.3 MT of food are globally wasted or lost per year (Gustavasson *et al.*, 2011). Reduction in these losses would increase the amount of food available for human consumption and enhance global food security (Mundial, 2008; Trostle, 2010).

The rising population growth rate in Africa has led to the high demand for rice in Sub-Saharan Africa and its consumption is growing faster than that of any other staple food in Africa (WARDA, 2008). In 2003, Ghana imported 415,150 MT representing 60% of the country's total rice consumption (LRAN, 2008). According to the Rice Almanac (2013), our earth needs additional 116 million MT of rice by the year 2035. In some countries such as China, Japan, and the Republic of Korea, the yield gap is closing. In considering the above fact, post-harvest and food loss-minimization is the only and priority focus area of the future to feed all mouths on the earth.

Over the past decades, significant focus and resources have been allocated to increase food production. For example, 95% of the research investments during the past 30 years were reported to have focused on increasing productivity and only 5% directed towards reducing losses (Kader and Roller, 2004; Kader, 2005). Increasing agricultural productivity is critical for ensuring global food security, but this may not be sufficient. Food production is currently being challenged by limited land, water, and increased weather variability due to climate change. To sustainably achieve the goals of food security, food availabilities need to be also increased through reductions in the post-harvest losses at farm, retail and consumer levels (Jaspreet *et al.*, 2013).

Apparently, there is no sufficient information on post-harvest losses of rice produced and other cereal grains in Ethiopia except very few studies under the Sub-Saharan Africa region. Due to this it is very essential to assess and evaluate the post-harvest losses of rice at different stages to take care of them and minimize losses. Having the lack of information about this important subject, this research topic is prioritized to be undertaken in Fogera plains of Amhara National Regional State which is the rice belt of the country.

## **1.6 Objectives**

### **1.6.1 General objective**

The main objective of the study was to determine the post-harvest loss of rice from harvesting to milling.

### **1.6.2 Specific objectives**

1. To quantify post-harvest losses of rice from harvesting to milling (harvesting, threshing, drying& cleaning, storage and processing),
2. To evaluate losses associated with the use of different types of milling machines (i.e one-pass and two-pass rice milling machine),
3. To assess the knowledge and practices of rice producing farmers on the reduction of post-harvest losses of rice in the post-harvest chain, and
4. To evaluate the efficiency of different storage materials or technologies used by farmers.

## **1.7 Research Questions**

1. Which post –harvest practices incur significant loss of rice?
2. What type(s) of rice milling machines used in the study area has good recovery rate?
3. What is the level of knowledge and practice of farmers and rice processors on rice post-harvest handling?
4. How do farmers store their produce and which of the storage technology (ies) is/ are more efficient?
5. What are the factors that aggravate the post-harvest loss in the locality?

## **1.8 Relevance of the study**

The study aimed at analyzing the different causes of post-harvest loss of rice from harvesting to milling. Providing a holistic picture of existing challenges and the severity of losses that occur in each practice and step. It would also serve as an input for rice growers, processors and development practitioners to take measures on post-harvest losses of rice. In addition, the findings also yield other valuable information for technology developer and serve as a policy-input for policy makers.

## **CHAPTER: 2**

### **2. LITERATURE REVIEW**

#### **2.1 Brief Background of Rice**

##### **2.1.1 Origin of rice**

The origins of rice have long been debated. The plant is of such antiquity that the exact time and place of its first development will perhaps never be known. It is indeed one of the most important developments in history. Rice has fed more people over a longer time than has any other crop (CGIAR, 2013 b).

Pottery shards bearing the imprint of both grains and husks of the cultivated rice species (*Oryza sativa*) were discovered at Non Nok Tha in the Korat area of Thailand. Plant remains from 10,000 B.C. were discovered in Spirit Cave on the Thailand-Myanmar border (CGIAR, 2013 b). In China, extensive archeological evidence points to the middle Yangtze and upper Huai Rivers as the two earliest places of *O. sativa* cultivation in the country. Rice and farming implements dating back at least 8,000 years have been found. Cultivation spread down these rivers over the following 2,000 years (CGIAR, 2013 b).

##### **2.1.2 Origin of African rice**

Two species of the genus are cultivated *Oryza sativa*, the universally cultivated Asian rice, and *O. glaberrima*, the West African cultivated rice. African rice is now only rarely grown in pure stands, but it is instead grown in mixture with the Asian rice in various proportions. The extent of even this form of mixed cultivation is diminishing as it is being replaced with 'pure' Asian rice (Nayar, 2010).

Porteres (1976) is almost the only author to have worked on the origin of African rice. He had suggested that it originated from the annual wild rice, *O. barthii*, about 3500 years ago in the Inland Niger River Delta (Mali) (IND). He also proposed that Asian rice was introduced into West Africa by European traders and colonialists in the 15th and later centuries. Some of his propositions, including the time of origin, have since been found to be incorrect (Gray, 1962).

However, his original views on the origin of African rice continue to persist in the literature (Nayar, 2010).

### **2.1.3 Africa's rice sector**

Rice is becoming an increasingly popular food in Africa because it is easy to store and cook, it is tasty and can be used for a large variety of dishes. It is grown in more than 75% of African countries, with a combined population of close to 800 million people. While it is already the main staple food crop in ten African countries, per capita consumption in others is rising at such a rapid pace in the coming years (EUCORD, 2012).

In 2008, Africa produced an estimated quantity of 26.5 million MT of paddy rice on 10.5 million hectares (FAOSTAT, 2010). The western, northern and eastern regions of Africa had the largest shares, with 10.2, 7.3, and 5 million MT, respectively. These quantities of paddy rice were harvested on 5.8, 0.8 and 2.4 million hectares in West, North and East Africa, respectively (EUCORD, 2012).

### **2.1.4 Ethiopian rice sector**

Ethiopia's elevation, terrain, and climate makes its agricultural system unique, allowing for multi-crop cultivation in small fragmented areas. There is a vast land and water resource still waiting to be developed. The hot-to-warm moist climates are potentially suitable for rice culture as they fulfill all the requirements of the crop. Hence, the time may not be too far for Ethiopia to be one of the major producers of rice in the world (Shahi, 1985). According to the NRRDSE (2009) GIS survey technique the country has 39,354,190 ha of rice production potential of this 30,501,524 ha were identified highly suitable and suitable for production while the rest is terminated as moderately suitable. However, the actual yearly area coverage of rice in the year 2016 was only 45,454 ha (CSA, 2016) which is about 0.1% of the potential production.

Today rice is produced mainly by small-scale farmers in many parts of the country and also with large scale farmers in few places. Total milled rice produced in 2014/15 was about 131,822 MT (CSA, 2015). Ethiopia adopted NERICA (new rice for Africa), the hybrids of *O.*

*sativa* and *O. glaberrima*) varieties such as NERICA-1, 2, 3, 4 and sparica-1 varieties in addition to the local varieties such as X-Jigna and others. Due to the introduction of upland and irrigated rice varieties in the country rice farming has grown from 19, 500 farmers in 2005 to over 284,868 in 2009. Currently twelve upland/lowland NERICAs and sativa types rice varieties were released in Ethiopia during 1999 and 2007 (NRRDSE, 2009).

## **2.2 Global Food Loss and Waste**

The assessment of global food losses and waste estimated that each year, one-third of all food produced in the world for human consumption never reached the consumer's table (FAO, 2011). This not only means a missed opportunity for the economy and food security, but also a waste of all the natural resources used for growing, processing, packaging, transporting and marketing food (FAO, 2015). Food wastage arises at all stages of the food supply chains for a variety of reasons that are very much dependent on the local conditions within each country. At a global level, a pattern is clearly visible; in high-income regions, volumes of wasted food are higher in the processing, distribution and consumption stages whereas, in low-income countries, food losses occur in the production and post-harvest phases (FAO, 2015).

A study by Institute of Mechanical Engineers indicates that the current agricultural practices use 4.9 Gha (global hectares or 4931 million hectares) of the total 14.8 Gha (14894 million hectares) of land surface on the earth (Fox and Fimeche, 2013). The sample study indicates that agricultural production in addition uses 2.5 trillion m<sup>3</sup> of water per year and over 3% of the total global energy consumption as well. Thus, the estimated food losses of about 30-50 % of total production, translate to wasting 1.47-1.96 Gha of arable land, 0.75-1.25 trillion m<sup>3</sup> of water and 1 to 1.5% of global energy (Fox and Fimeche, 2013). Food losses can be quantitative as measured by decreased weight or volume. On the other hand, it can be qualitative, such as reduced nutrient value and unwanted changes in taste, color, texture, or cosmetic features of food (Buzby and Hyman, 2012). Quantitative food loss defined as reduction in weight of edible grain or food available for human consumption. The quantitative loss is caused by the reduction in weight due to factors such as spillage, consumption by pest and also due to physical changes in temperature, moisture content and chemical changes (FAO, 1980).

Factors that contribute to food loss range from mechanization practices such as harvesting to handling, processing and others, to weather conditions, production practices, management decisions, transportation facilities, grading issues, infrastructure, consumer preferences/attitudes, and availability of financial markets. A typical post-harvest chain comprises a number of stages for the movement of harvested output from the field to the final retail market. The losses incurred at each step vary depending upon the organization and technologies used in the food supply chain. For example, in less developed countries where the supply chain is less mechanized, larger losses are incurred during drying, storage, processing and in transportation (Jaspreet *et al.*, 2013). In low-income countries, the lack of infrastructure and lack of knowledge on proper storage and food handling, combined with unfavorable climatic conditions, favor food spoilage. In higher-income countries, aesthetic preferences and arbitrary sell-by dates are factors that contribute to food waste (FAO, 2016). Food spoilage and waste account for annual losses of US\$310 billion (<http://publications.cta.int/en/publications/publication/PB007E/>) in developing countries, where nearly 65% of lost food occurs at the production, processing and post-harvest stages. In Sub-Saharan Africa alone, up to 150kg food produced is lost per person every year (<http://www.google.co.uk/url>).

El- Hissewy (1999) concluded that during harvest and post-harvest operations, the largest amount of losses was determined as large as 28.52 % when manual harvesting and threshing by tractor, (Treading) and transferring by men and traditional mills, were used. In general, the harvest and post-harvest losses ranged between 8.16 % and 28.52% and it differs according to the methods used during these steps. However, most of these losses were due to the use of the traditional mills.

### **2.3 Paddy Pre-harvest Operations**

The quantity and quality of final milled rice depend on the efficiency of farming management, field operations and post-harvest operations. Decisions are taken from planting to consumption of the rice crop. Initial decisions about the variety to be planted determine intrinsically desirable characteristics and depend upon consumer preference as well as the technical capacity of the farmers during production and post-production operations. These characteristics in turn become factors which influence efficiency, grain loss magnitude, choice of harvesting and threshing technology, rate and quality of the drying and de-husking process, and eventually



total recovery of the milled rice. Then, there are the wrong practices at the planting stage which can lead to losses: planting of red rice admixture, attacks by rodents and birds, poor weeding and a harvest-maturity date which can be too early or too late (Mejía, 2002).

## **2.4 Post-harvest Operations**

The postharvest sectors are still characterized by high losses. In Africa and Southeast Asia, losses generally range from 10% to 30%. These losses caused by, loss in weight through spillage, losses due to pests, low milling yields, inappropriate post-harvest management practices, delay in the post-harvest chain, outdated post-harvest equipment and infrastructure, and low operators' skills that lead to losses in quality along the chain and lower the market value of milled rice by 10–30% or more. Data available for rice post-harvest losses, based on field surveys and used here as an example, are quite extensive and represent the 'best case' compared with data for other crops. Several extensive studies suggest that about 15 percent of grain may be lost in the post-harvest system (Liang, 1993).

Climatic conditions are also an important consideration in determining the wider applicability of data. In humid climates, rice losses are generally greater at the drying stage (Grolleaud, 2002). Hodges (undated) reviewed grain losses in East and South Africa, attempting to compare loss rates in hot humid climates (where open storage structures were required to maintain airflow) and hot dry climates (favoring sealed storage designs). Hodges concluded that data on storage losses were too limited to permit reliable comparisons of loss rates under different climates. In common with other authors, Tyler (1982) suggested that the aggregated data reflecting losses on a worldwide basis are of little value. Long-term studies of post-harvest losses in Zambia and India were identified as using 'reliable methodology' and indicative of the fact that when post-harvest losses are determined by field survey, storage and related post-harvest losses are usually lower than previously reported (Tyler, 1982).

Most of the post-harvest losses of grain crops happen during the drying and storage operations. Farmers in Bangladesh experienced huge loss of paddy due to delayed or improper drying which estimated 1.56 to 5% in addition to the estimated 14% loss from cutting to storage. It is necessary to adopt adequate drying technologies at the farmers' level to reduce post-harvest losses and produce high quality paddy seed (ADM, 2015).

## **2.5 Post-harvest Loss Assessment**

### **2.5.1 Harvesting losses**

Harvesting is the process of collecting the mature rice crop from the field. Harvesting of paddy includes cutting, stacking, handling, threshing, cleaning and hulling of paddy. The goal of good harvesting methods is to maximize grain yield, and to minimize grain damage and quality deterioration. Harvesting can be done manually using sickles and knives, or mechanically with the use of combine harvesters. Regardless of the method, a number of guidelines should be followed that will ensure that harvest losses are kept to a minimum and grain quality is preserved during harvest operations (IRRI, 2013 a). For harvesting the grain moisture content ideally is between 20-25% or crop should be cut when 80-85% of the grains are straw (i.e., yellow) colored. If the crop is too dry, fissures will form in dry kernels when these are re-wetted and high shattering losses might occur. Fissured grains break when milled. If the grain is too wet, it is more difficult to remove grain from the panicle and some damage may occur during machine threshing (IRRI, 2013 a).

### **2.5.2 Threshing losses**

For hand-threshed crops, partial drying in the field for a couple of days may be necessary to lower the moisture content and make threshing easier. The highest milling yield attained for hand-threshed, sun-dried rice at a grain moisture content of 18-20%. Care must be taken not to over-dry the crop if it is to be transported any distance before threshing as excessive shattering will occur. While the crop dried before threshing, dried crop should not subjected to re-wetting. Re-wetting causes grain fissures, which lead to a high amount of broken grain in milling. In wet crop conditions, manual threshing is difficult if the crop is not sufficiently dried (IRRI, 2013 a).

Threshing losses were higher (6.14%) in the sickle-harvested rice that used the “bambam” (a locally made big wooden box) than in the panicle-harvested rice (2.45%) that used the bag-beating method. Threshing in an enclosed room where escaping grains could be trapped on tarpaulin, may help reduce threshing losses which especially occurs in the “bambam” method since scattered grains can be collected (Appiah *et al.*, 2011).

### 2.5.3 Drying losses

Drying is the process that reduces grain moisture content to the level where it is safe for storage. It is the most critical operation after harvesting a rice crop. Delays in drying, incomplete drying or ineffective drying will reduce grain quality and result in losses (IRRI, 2013 b). Drying and storage are related processes and can sometimes be combined in a piece of equipment (in store drying). Storage of incompletely dried grain with a higher than acceptable moisture content will lead to failure regardless of what storage facility is used. In addition, the longer the desired grain storage period, the lower the required grain moisture content must be (IRRI, 2013 b). Harvested grains with high moisture content must be dried within 24 hours to 14 percent for safe storage and milling, or at most 18 percent for temporary storage of 2 weeks when it is not possible to dry any faster. Delayed drying may result in non-enzymatic browning (stack-burning), microbial growth and mycotoxin production in parboiled rice (NRI, 1991).

Losses due to bad drying practices ranges from 1 to 5% and it is mainly the quality which is affected. Good drying is crucial for minimizing post-harvest losses, since it directly affects safe storage, transportation, distribution and processing quality (Mejía, 2002).

**Table 1:** Amount of moisture content (MC) and possible storage period.

<b>Duration of storage</b>	<b>Required MC for safe storage</b>	<b>Probable nature of harmful effect</b>
Weeks to a few months storage	14 % or less	Molds, discoloration, respiration loss, insect damage, moisture adsorption
8 to 12 months storage	13 % or less	Insect damage
Farmer's seeds	12% or less	Loss of germination
Storage for more than 1 year	9 % or less	Loss of germination

Source: IRRI (2013 b). Paddy drying manual.

### 2.5.4 Storage

In Asia, between 70 and 90 percent of farm-produced paddy remains in the farms and the rest deposited to agricultural cooperatives or sold to the private sector. Appropriate storage is

therefore required, both for consumption (milled or paddy) and seed purposes. Unfortunately, small-scale or marginal farmers often lack the resources to store large amounts of grain and do not have a large storage structure; they therefore are obliged to sell their paddy to traders or buyers immediately after harvest (Mejía, 2002).

The traditional storage structure used by farmers in Asia is a container made of woven bamboo, palm leaves or wood. Problems occurring include: spoilage due to high grain moisture, rain strips, storms or flooding, dirt contamination, losses due to insects, rodents and even theft and collapse of the structure (Lantin, 1997). The paddy retained for storage is sun-dried several times and cleaned before loading into the storage container. The farmer determines the dryness required for storage is on basis of experience. Dryness is measured by pressing a bunch of grains hard into the hand or biting several grains: a fully dried grain is hard. Paddy is usually stored with a moisture content of 14 percent or less. Losses in farm storage have been estimated up to 6.2% (Ren-Yong *et al.*, 1990).

In Africa, for example, without adequate storage facilities and transportation, 10 to 20 percent of the continent's Sub-Sahara grain succumbs to enemies such as mold, insect, and rodents. That is four billion dollars' worth of food, enough to nourish 48 million people for a year (National Geography News, 2014). Rice storage facilities take many forms depending on the quantity of grain to be stored, the purpose of storage, and the location of the store. In general, it is recommended that rice for food purposes should be stored in paddy form rather than milled rice as the husk provides some protection against insects and helps prevent quality deterioration. However, when rice can be stored as brown rice, 20% less storage capacity will be needed (IRRI, 2013 c).

Rice grain is hygroscopic, the grain moisture content will eventually equilibrate with the surrounding air. High relative humidity and high temperatures contribute to high equilibrium or final moisture content. In many tropical countries, the equilibrium moisture content is above safe storage moisture levels (IRRI, 2013 c). According to the IRRI (2013 c), safe storage of rice for longer periods is possible if three conditions are met:

- Grain is maintained at moisture levels of 14% or less, preferably at 12% or less
- Grain is protected from insects, rodents, and birds
- Grain is protected from re-wetting by rain/imbibing moisture from the surrounding air.

### **2.5.5 Milling**

The objective of a rice milling system is to remove the husk and the bran layers from paddy rice to produce whole white rice kernels that are sufficiently milled, free of impurities and contain a minimum number of broken kernels. The milling yield and quality of rice is dependent on the quality of the paddy, the milling equipment used and the skill of the mill operator. The rice milling operation is the separation of the husk (dehusking) and the bran (polishing) to produce the edible portion (endosperm) for consumption. Although a theoretical mill recovery would be between 71 and 73 percent, in practical terms it is possible to obtain between 68 and 70 percent from a good variety of paddy. Milling losses can be reduced by adopting small-scale modern rubber roll sheller and introducing parboiling of paddy before milling (Mejía, 2002).

The extent of losses in the edible portion of the grain depends on a variety of factors, including variety of paddy, condition of paddy during milling, degree of milling required, kind of rice mill used, the operator's skills, and insect infestations. The milling operation produces husk, milled rice, germ, bran and broken rice, coming out as mixed products, depending on the rice mill used. The ideal moisture content for milling is 14 percent, as wet soft grain results in a powdery product, while very dry brittle grains result in broken and powdery material (Mejía, 2002).

### **2.5.6 Rice milling machines**

#### **2.5.6.1 One-pass milling**

The single-pass rice mill is an adaptation of the "Engleberg" coffee huller. This type of mill is still very popular in many of the poorer rice-growing countries and is widely used for custom milling of household rice. It is also still popular for milling parboiled rice in Bangladesh and many African countries. This mill is a steel friction type mill and uses very high pressure to remove the hull and polish the grain. This results in many broken kernels, a low white rice recovery of 50-55% and head rice yields of less than 30% of the total milled rice. The fine broken ones are often mixed with the bran and the ground rice hull used for animal feed. The poor performance of the Engleberg mill has led some governments to discourage its use and in

many Asian countries, the Engleberg mills can no longer be licensed to operate as service or commercial mills (IRRI, 2013 d).

#### **2.5.6.2 Two-pass milling**

Two-stage mills are often called compact rice mills and in many countries have superseded the Engleberg mill. The two-stage mill has separate hulling and polishing processes. Rubber rollers remove the husk and the brown rice is then polished with a steel friction whitener similar to the Engleberg. These mills have a mill capacity of 0.5-1 ton paddy per hour and are often used for custom milling in the rural areas. The milling performance of the compact rice mill is superior to the single-pass Engleberg huller with milling recoveries normally above 60% (IRRI, 2013 d).

#### **2.5.7 Operators' skills**

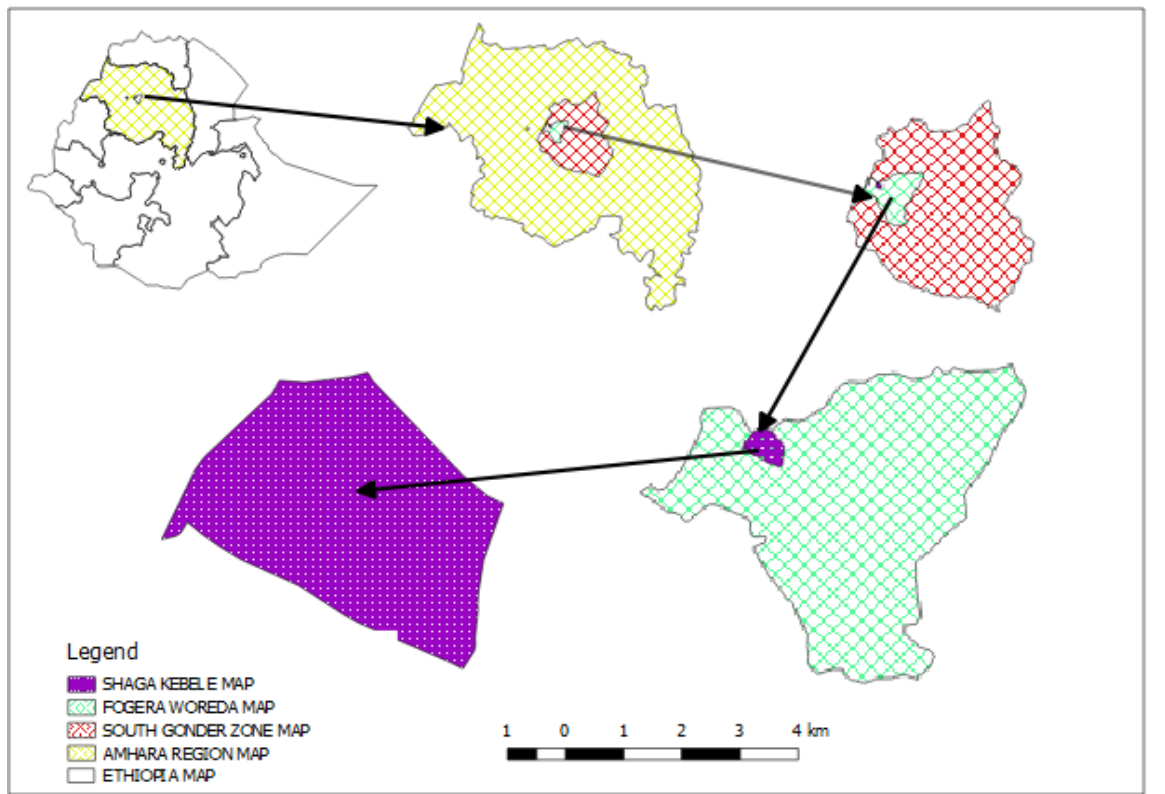
There are good and poor rice mill operators. Often, the mill operator is an untrained apprentice who has picked up skills on the job. An operator who is continually adjusting valves, hammering ducts, and screens does not have the required skills. In properly designed mills there should be very little adjusting required with the machines, once a steady state in the grain flow is attained. The mill of such operator's however, is often dusty, dirty, with ducts and high breakage and poor milling recovery (IRRI, n.d). The milling yield from the three different individual millers ranged from 66.8% to 68.53%. The results were obtained by allowing the millers milled from the same milling machine. The different millers showed significant differences in their abilities or skill in milling (Ramatoulaye, 2010).

## CHAPTER: 3

### 3. MATERIALS AND METHODS

#### 3.1 Description of the study area and administrative classification

This research was conducted in Shaga kebele, Fogera district of Amhara National Regional State (ANRS). The district is situated in the North West of Ethiopia 625 km away from Addis Ababa and 55 km from Bahir Dar town on road from Addis Ababa to Gondar road with a geographic coordination of  $11^{\circ}46'$  to  $11^{\circ}59'$  latitude North and  $37^{\circ}33'$  to  $37^{\circ}52'$  longitude East. Fogera is one of the 10 districts in South Gondar zone bordered by Libokemkem district on the North, Derra district on the South, Fartta district on the East and Lake Tana on the West. This particular research site (Shaga kebele) is one of the 32 kebeles administered under the Fogera district. It is also one of the major 16 rice grower kebeles bordered by Libokemkem district on the North, Shina Teklehaymanot kebele on South, Woreta town on the East and Nabega kebele on the West.



**Figure 1:** Map of Ethiopia, Amhara region, South Gondar Zone, Fogera district/Woreda and the study Kebele.

### **3.2 Topography and climate**

According to the Fogera district land administration office 2017 land use update, the Fogera district's total area of land is about 110,810 ha of which 76,394 ha are arable, 5140 ha are under forest coverage, 15,708 ha are grazing land and 13,567 ha are covered by houses, rivers, gorges and sloppy mountains. The areas annual rainfall ranges between 1336mm and 1003mm respectively and June to October is the main growing period (rainy season). The maximum and minimum temperature of the district is 27.3<sup>0</sup>C and 11.48<sup>0</sup>C respectively with average temperature of 19<sup>0</sup>C, which is suitable for rice production, the maximum and minimum elevations of localities are 2410m and 1774m respectively above sea level.

### **3.3 Demographic structure**

According to the Fogera woreda finance and economic development (2016/17) forecast, the total population of the study kebele is 2,715 household and the district is estimated to be 253,790 (49 % female and 51 % male). Out of this, 96.9% are living in rural areas and the remaining 3.1 % resides in towns. As regards the age distribution of the population, 45.22% fall in the age group of 0-14 years, 42.91% in the age of 15-49 years and the rest 11.87% make up the age group of >50 years.

### **3.4 Farming system of the district**

According to Fogera office of agriculture 2016 annual report out of the total 59,390 ha of suitable farm land area rice covers 21,341 ha, maize 12,576 ha, finger millet 10,846 ha, Teff 5692 ha, barley 3582 ha, and pepper 1529 ha and 3,824 ha other crops (see appendix 5).

### **3.5 Experimental procedure**

The experiments have been conducted in two ways, practical fieldwork on the farmers' farm land by using 'Tile plot of board method' and house-hold survey (interview via questionnaire). This study addressed only the quantitative loss that occurred during harvesting, threshing, drying and cleaning, storage and milling by two different milling machines. Fogera district was selected purposefully for this research as it is the rice belt of the country where 46% of the national and 70% of the Amhara region rice is produced (CSA, 2015/16). Under the district,



Shaga kebele was selected purposefully since it represents geographically both the low-land (high flooded) and relatively the upland rice ecology.

The total of 70 rice grower households were selected randomly following the “square root of the number of farming households or population” (APHLIS, 2014) for the survey and five farmers were selected purposefully for the field sampling of harvesting and threshing work. Focus group discussions were also conducted with processors to assess the milling situation.

No of sampling unit= $\sqrt{\text{Total population}}$ . .....Eques. 1

Source: (APHLIS, 2014)

### **3.6 Data source and method of data collection**

#### **3.6.1 Primary data collection**

The primary data collection has been done on producers’ household survey, key informants interview with the processors, practical field data collection related to harvesting, threshing, measuring of storage loss in three different storage materials, drying and cleaning loss as well as milling loss data using two different milling machine on practical basis. Personal observation and grain moisture content records were also undertaken at each step.

#### **3.6.2 Secondary data**

Important and necessary data were collected and analyzed that sourced from office of agriculture. Farming system and extension support on PHL, Rice production area and production trend, challenges and opportunities of rice PHL reduction etc. Number of processors and processing machines data was collected from Woreta town trade office, demographic and land use administration data were collected from Fogera district office of finance & economic development and land use administration respectively. Discussions were also conducted with the national rice research and development experts on undergoing research agenda and future opportunities on the rice research and development program as a whole and in particular rice PHL. In addition, review of relevant literature on rice postharvest and processing conducted and used in a manner fit for this research.

### **3.6.2.1 Producers household survey**

The data on producers household were collected through interview using data sheet and the primary data denoted to 2016/17 production season. Major activities on the post-harvest operations (including harvesting, threshing, cleaning and drying, storage and milling), challenges and factors that aggravate the post-harvest loss were collected from sample respondents through a structured questionnaire, which was designed to generate data on some social, economic and sector issues that supposed to be important for this post-harvest loss study. This enabled the collection of both quantitative and qualitative data from a total of 70 sample households by well-trained and experienced enumerators. The enumerators were equipped with the necessary interview tools, trained on methods of data collection and interview techniques before they were employed for data collection.

### **3.6.2.2 Focus group discussion and key informant interview**

Key informants (knowledgeable observers of the sub-sector) were identified and interviewed in order to obtain their views, opinions and suggestions about post-harvest loss of rice and in general on the rice sector. The key informants interviewed were from the office of agriculture experts, researchers, marketing experts, figurative processors and farmers to get additional insight on PHL of rice across the supply chain and the processing equipment scenario.

## **3.7 Experimental Design and Research Method**

A completely randomized design (CRD) with factorial arrangement was used for the experiment of storage loss. Three different storage materials with three replications was used at farm gate storage or the farmers' house to evaluate the storage loss of three different materials. The treatments were placed randomly using lottery system. 'Tile plot of board method' was also used to assess the harvesting loss at the farmer's field.

### 3.8 Post-harvest Loss Studies

#### 3.8.1 Determination of harvesting loss

With standing rice crop therein were selected 4mx4m area in three replications on selected five farmers' field diagonally and harvested by skilled man using sickle in the same way as farmers do on the rest of their fields. Before harvesting, three samples of grains were collected for the moisture content determination. Moisture contents of the grains were measured using the Japan-made digital moisture measuring tool. The harvested stalk stayed in field and dried for two days, after that the stalk were threshed, cleaned and weighed by using spring balance. The shattered grains on the harvested plots were collected exhaustively, cleaned, weighed using digital balance and moisture content of the grains determined and adjusted to 13% moisture using the standard moisture correction (equation 3). The percentage of harvesting losses were determined by weighing of collected paddy rice on the harvested area divided by the total amount of harvested paddy grains of that particular area multiplied by 100 (equation 2).

$$\text{Harvesting loss (\%)} = \left( \frac{\text{Weight of collected grains}}{\text{Total harvested and threshed grains weight}} \right) \times 100 \dots\dots \text{Equation. 2}$$

Source : (Ramatoulaye, 2010)

$$\text{Weight of grain} \times \frac{100 - \text{moisture content by meter}}{100 - \text{the intended moisture to be}} = \text{corrected moisture} \dots\dots \text{Equation. 3}$$

Source: (Harris and Lindblad, 1976))

#### 3.8.2 Determination of threshing loss

Threshing loss was determined from oxen threshed fields. For this purpose, five farmers were identified and the threshed grains left on threshing field and on straw were exhaustively collected. The threshing fields were divided in-to eight parts equally and data were taken from four partitions. On the other hand, the straw data were collected by bundling the whole straw from a similar strip length and 25% of the bundles were exhaustively searched for the paddy grains attached to the straw (see the picture in the annex 6). Intact grains on the straw and left-over grains on the smeared wall of threshing confinement were collected carefully and cleaned,

weighed and the data recorded after adjusting to 13% moisture content. Finally, the percentage of loss was calculated using the formula given below.

$$\text{Threshing loss (\%)} = \left( \frac{\text{Weight of collected grains on the threshing field \& straw}}{\text{Total weight of threshed grains}} \right) \times 100 \dots \text{Eques. 4}$$

Source: (Ramatoulaye, 2010)

### 3.8.3 Determination of cleaning and drying loss

An experienced woman has been hired to take care of both the cleaning and drying of paddy for four hours. Twenty five kilo grams of paddy rice were cleaned and dried in three replications on canvas using local cleaning techniques (manual cleaning) by using “sefed” (flat-shaped tool made from grass and used for cleaning). The grains positioned out of the canvas during cleaning and drying processes were collected carefully and weighed using digital balance. The cleaning and drying loss data thereof were calculated by using the following formula.

$$\text{Cleaning loss (\%)} = \left( \frac{\text{Weight of collected grains}}{\text{Total weight of paddy rice cleaned}} \right) \times 100 \dots \text{Eques. 5}$$

Source: (Ramatoulaye, 2010)

### 3.8.4 Determination of storage loss

Three different storage technologies (the ordinary poly-propylene bag, Purdue improved grain storage (PICS) bag, and the dominantly used local storage “Gotta” (made from mud and straw and used for storage of grains) were deployed at the farm gate storage contain 25kg of paddy rice for each storage techniques for 5 months in three replications. Weight and moisture content measurement were undertaken at the beginning of storage time. Mid-season weight measurement were also taken after 75 days (two and half months’ time of the full storage time), finally at the end of 150 days (five months) of paddy grains were sampled for their final weight and moisture content. Each paddy materials were milled using one-pass milling machine (N90) milling machine to measure the impacts of each storage materials on the milling recovery rate. The storage loss was calculated by using the following formula.

$$\text{Storage loss (\%)} = \left( \frac{\text{Initial weight} - \text{final weight}}{\text{Initial weight}} \right) \times 100 \dots \text{Eques.6}$$

Source: (Ngatia and Kimondo 2011)

### **3.8.5 Determination of milling loss**

#### **3.8.5.1 Determination of paddy milling loss**

The commonly used rice milling machines i.e. two-pass (the SB type) and one-pass (the N type) were deployed to evaluate their performance for rice milling recovery rate. For this purpose, 25kg of uncleaned paddy rice were milled at a moisture content of 12.2% in three replications. The milled rice weight was measured and the recovery rate was calculated by using the following formula.

$$\text{Milled rice yield (recovery \%)} = \left( \frac{\text{Weight of polished rice}}{\text{Weight of paddy rice}} \right) \times 100 \dots \text{Eques. 7}$$

Source: (Ramatoulaye, 2010)

#### **3.8.5.2 Determination of parboiled rice milling loss**

Determination of parboiled rice milling loss was conducted using two-pass milling machine. Twenty five kg of rice were cleaned, washed, soaked in cold water for 14 hours and then steamed for four hours and subsequently dried under shade for five days. The dried parboiled rice was milled by using two-pass milling machines in three replications. The parboiled rice grains were weighed and the recovery rate were calculated (equation 7).

### **3.8.6 Determination of different millers efficiency**

The performance of two millers were assessed using one-pass milling machine. For this purpose, the two millers were deployed to mill 25kg of cleaned paddy rice in three replications. After milling, both the polished rice and the bran were weighed and the recovery rate for each miller was calculated in the following manner. Then afterwards, their efficiency was calculated according to the recovery percentage (equation 7).

### 3.8.7 Determination of head rice (unbroken) and broken grains

The head rice percentage of milled rice were evaluated for the tow different machines and millers the breakage level exposed. Ten (10g) of samples were taken from de-husked brown and de-husked parboiled from two-pass machine and polished white from one-pass machine on the two millers yield. The head and broken rice samples were carefully separated by hand and weighed. Where the head rice is >75% of the full grain size ([www.knowledgebank.irri.org/.../rice.../physical-quality-of-milled-rice-fact-sheet](http://www.knowledgebank.irri.org/.../rice.../physical-quality-of-milled-rice-fact-sheet)). Finally, the proportion of broken and head rice was determined according to the following formulas (Firouzi *et al.*, 2010).

$$\text{Head rice (\%)} = \left( \frac{\text{Weght of head rice grain}}{\text{Weight of sampled milled rice grains}} \right) \times 100 \dots \dots \dots \text{Eques. 8}$$

$$\text{Broken rice (\%)} = \left( \frac{\text{weight of broken rice}}{\text{Weight of sampeled milled rice grains}} \right) \times 100 \dots \dots \dots \text{Eques. 9}$$

### 3.9 Data Analysis

The Statistical Package for Social Sciences (SPSS) version 20 was used to analyze the data for survey questionnaire, the field sample survey of harvesting, threshing, drying and cleaning, milling and Storage loss measurements.

## **CHAPTER: 4**

### **4. RESULTS AND DISCUSSION**

#### **4.1 Survey on Farmers Level of Understanding on Rice Postharvest Losses**

##### **4.1.1 Age, marital status and family size of the household**

This survey was conducted to comprehend the farmer's knowledge and perception of rice post-harvest losses from harvesting to milling. Seventy (70) rice farmers in "Shaga" kebele were interviewed to collect qualitative and quantitative data on rice post-harvest system, of which 78% are male-headed, and the rest 22 % are female-headed households. The age of the household is a very important factor for early adoption of the extension service as well as to receive improved technology that enhances the rice post-harvest operations and reduce losses. As indicated in Table 5, the mean age of the respondents was 40.67 ( $\pm 11.55$ ) years, this finding is almost in line with (Yenenew, 2015) 42.1 years. This age is the active and productive age category that can contribute positively for PHL reduction.

Marital status positively contributes to PHL reduction as married households have more labor to be engaged in rice PH activities than unmarried, divorced and widowed ones. From the households interviewed, 90% are married, 4.3% are unmarried and the remaining 5.7% are divorced and widowed nearly in line with 87.2% and 4.3% reported by (Yenenew, 2015). On the other hand, the HH (household) family size has a positively correlation with PHL reduction in which the farm HH with a more labor has high chance for carefully and timely management of rice harvesting. In this survey the average family size was 5.8 with the minimum and maximum of 2 and 12 family size respectively. The family is main labor source for rice production, where 43% are under the age of 15-49 years which is a potentially hard working period.

##### **4.1.2 The household educational level**

Among the sample household heads, 47.1% of the respondents are unable to read and write, 42.8 % attended primary-secondary cycle (1-8).. 7.1 % attended adult education (able to read and write), and only 2.8 % completed secondary school (grade 9-10). This finding is somewhat

higher who reported 39.7% for unable to read and write, 27% primary second, lower than 29% adult education and in line 2.6% secondary school (Yenenew, 2015). As clearly shown, nearly 50% of the respondents are illiterate that could affect the extension and technology adoption rate to minimize the rice post-harvest loss.

**Table 2:** Demographic characteristics of sample of respondents

<b>Description</b>	<b>Frequency</b>	<b>Percent</b>	<b>Remark</b>
<b>Sex (%)</b>			
Male	65	92.31	
Female	5	7.69	
	<b>Mean (+SD)</b>	<b>Minimum</b>	<b>Maximum</b>
Age	40.67 (+11.54)	21.0	68.0
Family Size	5.8(+2.04)	2.0	12.0
<b>Marital Status (%)</b>			
Married	63.0	90.0	
Unmarried	3.0	4.3	
Divorced	2.0	2.9	
Widowed	2.0	2.9	
<b>Level of education (%)</b>			
Unable to read and write	33.0	47.1	
Able to read and write	5.0	7.1	
Primary first cycle (1-4)	12.0	17.1	
Primary second cycle (5-8)	18.0	25.7	
<b>Secondary (9-10)</b>	2.0	2.8	

#### **4.1.3 Landholding size and farm productivity**

The mean land-holding size of sample respondents was 1.00 ha in which 89.8% of the respondents own land area between 0.5-1.5 ha, 37% of the respondents replied that they have rented an average of 0.4ha of rice land on top of their own holdings. The average rice productivity of the area according to this sample survey is 41.51 quintals/ha of paddy (before de-dusking or polishing) with the minimum and maximum productivity of 27 and 62 quintals



respectively. This result is lower than the findings of Mekuria (2015) who reported average yield of 48 quintals which is higher than the national average of 27 quintals and 31 quintals South Gondar zone average (CSA, 2016). On the other hand, this figure is almost equal to the NRRSD (2009) projection for the year 2014 Amhara region productivity which is 40 quintals/ha and less than for the year 2019 projection which is 50 quintals. These productivity variations are most likely due to the varieties that are grown in other areas having low productivity due to their upland nature hence, lower the national productivity as compared to the potential low-land rice varieties productivity. The farmers have infant experience on rice as compared to the indigenous crops, where 7.1% of the respondents have an experience of 20 years and above, 65.7% of the respondents have 15-19 years of experience, 17.1% of the respondents have 10-14 years of experience and 10% of them have 5-9 years of experience. This experience is very low as compared to other crops that they have acquainted for long time learned the techniques of cultivation from their ancestors.

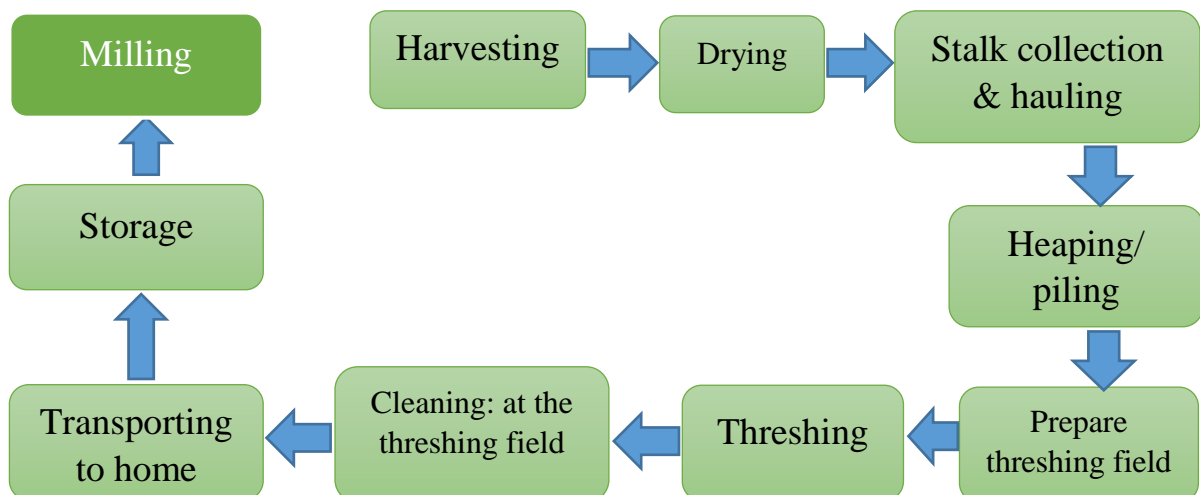
#### **4.1.4 Over view of rice post-harvest activities**

Farmers determine the harvesting period for rice through eye observation of the panicle and leaf color. They are going to decide to harvest when the field looks yellow and the soil is a bit dried, farmers believe that the harvesting in a wet soil causes too much harvesting loss and thus they prefer to stay a while until the soil moisture dried. Based on the field moisture data collection on 52 at harvesting period using SATAKE digital grain moisture meter revealed that farmers harvest at the moisture content of 15-19% which is below the recommended harvesting moisture content of 20-25% (IRRI, 2013 a).

The rice harvesting activates according to the study area which include:

- Harvesting using sickle This is the very beginning of the post-harvest operations where 100% the respondents agree.
- The cut rice/stalk stays in the field for about 1-3 days for sun drying where 100% the respondents agree.
- The stalk collected first to make the heaping process easy and then hauling to the place where it will be going to heap/pile, this is the main activity that women are highly involved as compared to the other rice PH activities where 79% the respondents agree according to the availability of man power.

- The heaping on average will stay 15-20 days before threshing as farmers believe that this will make the threshing easier and comfortable where 83% the respondents agree. This storage period is too long when compared to the recommended immediate threshing for machine harvesting and or/temporary piling (IRRI, 2013 a) .
- Threshing field is prepared on the ground by demolishing the soil clods and using water and straw, the wall compacted by foot to make it smooth where 100% the respondents agree.
- The other main activity is threshing which is done with the support of oxen track where 100% the respondents agree.
- The threshed paddy rice is cleaned at the threshing and is done by blowing to the wind and separated pure paddy from other impurities and then bagging is done, where 100% the respondents agree.
- Transportation: Donkey take the lion share for transportation of paddy from farm to home and from home to milling where 69.7% the respondents agree.
- Storage: the locally constructed storage material ‘Gottera/Gotta’ and poly-propylene bags are the available storage materials in the area where 100% the respondents agree.
- Milling: is the final and major activity where 100% the respondents agree.



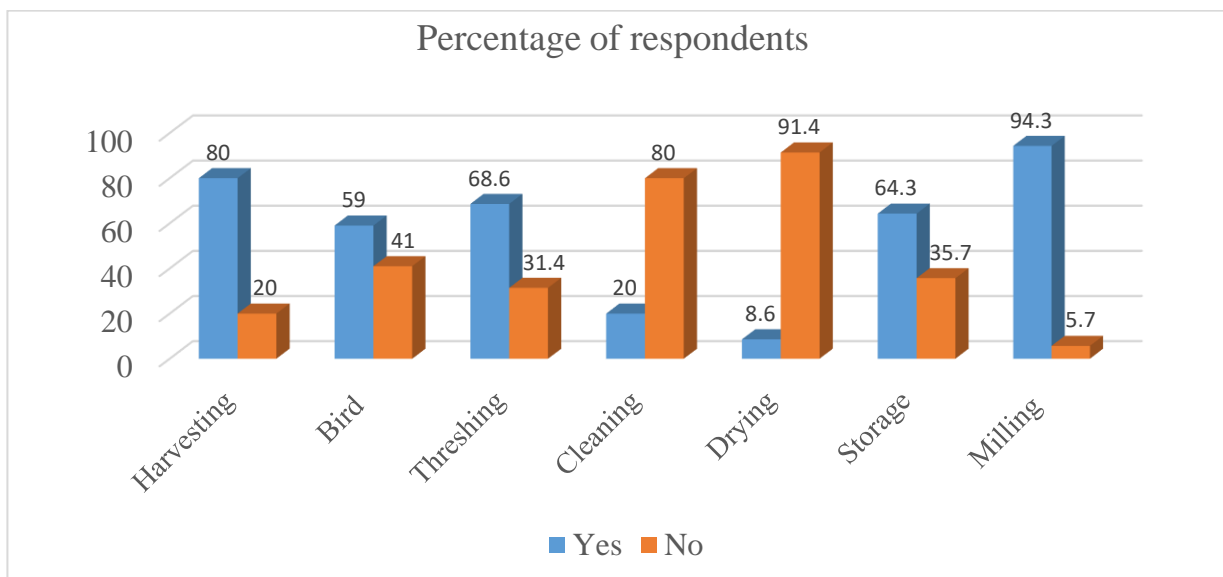
**Figure 2:** Major rice PH activities step-wise

#### **4.1.5 Post-harvest loss of rice and its cause**

According to this study, 100% of the respondents believed that their rice is lost at every step from harvesting to milling and these results are nearly similar to those of (Ramatoulaye 2010) where in 95% of the producers agreed to the existence of PHL. Harvesting is the most important activity in the post-harvest operations, wherein 80% of the respondents believed that harvesting causes very significant post-harvest loss and the rest 20% believed it insignificant (figure. 3). The second most important post-harvest operation is threshing, wherein 68.6% of the respondents believed threshing causes PHL significantly and the rest 31.4% believed it has no impact. Bird attack has been witnessed that it causes post-harvest loss, whereas the species are quite big, damage the rice stalk by their feet and eating the grains. In this respect, 59% of the respondents replied that the effect this bird is quite significant while the rest 41% responded insignificant (figure 3).

Paddy rice drying is not as such a common practice and nearly all of them dry enough the stalk with 91.4% of the sample respondents affirmatively and only 8.6% of them dry the grains when rain comes at threshing and the paddy gets wetted. Cleaning is also done at the threshing field by blowing to the wind with spoon-like materials made from wood. Further, 80% of the respondents did not clean paddy grain and only 20% of them clean it at home. Generally, farmers believe that cleaning and drying causes insignificant post-harvest loss in volume.

Storage and milling losses make other set of contributors of post-harvest loss. Rats, weevils and domestic animals are the main causes for storage loss. According to this survey results, 64.3% of the respondents believed that post-harvest loss occur at storage while the rest 35.3% responded that loss did not occur at storage. Unlike other cereals, rice will not be ready for consumption before de-husking and polishing of the hard cover (bran). The removal of bran also experiences rice loss either in the preparation for or during milling. According to this study, 94.3% of the respondents believed that post-harvest loss occurred at milling and the rest 5.7% feel that there is no loss at processing.



**Figure 3:** Percentage of respondents reflecting on the existence of post-harvest loss at various steps.

#### 4.1.6 Rice storage period and storage materials

The locally made storage material ‘Gotta’/‘Gotera’ is dominantly used for storage, especially for the one that will be stored for long period of time. According to this survey, 94.3% of the respondents’ stored rice using local-made material and poly-propylene bags while 5.7% used only the local material. In the meantime 98.6% the respondents also pointed out that the storage loss on account of poly bags is higher due to damage easily caused by rats and home animals as compared to the local storage material.

Rice is both staple food and cash crop in the area under investigation. According to the farmers, 50% of the produced paddy is allocated for market and the rest 50% used for household consumption. In most cases during pick production season the price of rice falls down therefore, at this time farmers’ hold and store the paddy rice for six to nine months for price speculation (in the hope of a better market price). Whereas, the house-hold consumption stayed for a year till the next harvest is ready.

#### 4.1.7 Rice milling and milling machines

Farmers mill the paddy rice at private milling owners in Woreta town. They are required to travel 1-2 hours on foot to get milling service and to market the rice. Due to the swampy nature

of the area, the Kebele has no road accessibility like other kebeles through the URAAP (universal rural road access programme) hence, donkey and human force are the only means to transport the produced rice to the town. Farmers' use two different types of machines i.e., one-pass and two-pass according to the purpose of milling either for consumption or for marketing. They use the two-pass type for home consumption, believing that the brown rice (rice with only the husk removed) as 'enjera' quality is quite better (soft) and has more recovery rate up to 78-82%. Whereas the one-pass type milling machine product or the white rice (rice with both the husk and the bran layer removed) 'enjera' quality is very rough, easily dried, and unattractive in appearance and has low milling recovery up to 65-70% only. These recovery rates are quite similar to those of IRRI, [http://www. Knowledgebank.irri.org/step-by-step-production/postharvest/milling](http://www.Knowledgebank.irri.org/step-by-step-production/postharvest/milling) i.e., 80% for brown rice and 68-72% for white rice. The reason why farmers use to mill the marketed rice using one-pass milling machine is because, the market requires white rice only.

#### **4.1.8 Effect of milling period on the milling performance of paddy rice**

The recovery of rice milling and head rice is the combination of several factors, among them the moisture content is the single most limiting factor which is directly or indirectly related to the storage condition and milling period. According to this survey, 63.2% of the respondents believed that the highest breakage occurred during early milling period. On the other hand, 36.8% of the respondents argued that the highest breakage occurred due to late milling due to over moisture loss.

**Table 3:** Effect of milling period on the breakage level loss of milled rice

Variables	Response	Frequency	Valid percentage	Percentage share of each reason	Justifications
Early milling causes high breakage	Yes	43	63.2	55.3	The paddy has too much moisture content
				44.7	During the PH activities the paddy has lost its moisture and then it breaks easily
Late milling causes the highest breakage	No	25	36.8	100	The paddy rice has lost its moisture through the passage time
Missing value	0	2	0	0	0
Total sample respondents		70	100		

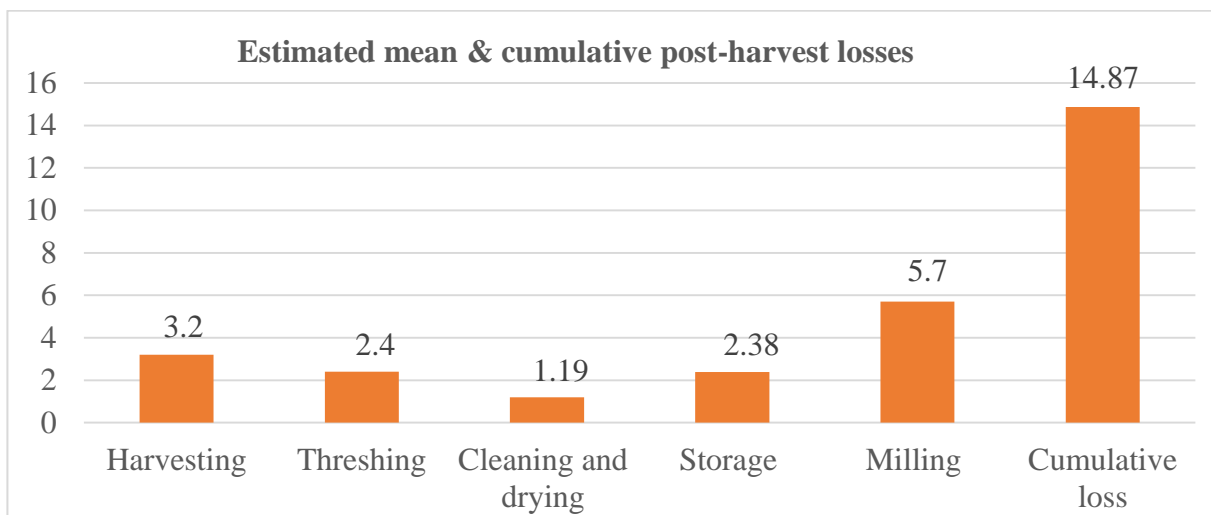
#### 4.1.9 Millers efficiency

Due to obsolete rice milling machines available in the area, almost all of milling technicians are operating through experience. In addition, due to the market demand of very white rice the millers tighten up the roller to polish thoroughly that could end up with high breakage, low recovery and excessive bran. According to this study, 100% the respondents agreed that the miller's skill affects the milling recovery rate. Ramatoulaye (2010) showed the significance of three millers extraction rate ranging from 66.8%-68.53%. According to the respondents not only the skill of the operators but also the behavior of millers affects the recovery rate, especially when there is a disagreement they let the rice grains to break a lot.

#### 4.1.10 Quantification of post-harvest losses

As we have seen in the aforementioned paragraph, all the sample respondent farmers agreed on the existence of post-harvest loss even though it varies depending at what step it has occurred and its magnitude. According to the survey respondents, the highest loss has occurred at milling which is 5.7% and the lowest loss has occurred at cleaning and drying which is 1.19%. The cumulative loss estimation by the respondents revealed that 14.87% of rice post-

harvest loss occurred at harvesting, threshing, drying & cleaning, storage and milling (Figure 2). These findings are nearly similar to those of (Julian Parfitt, *et al.*, 2010) who reported 15% total post-harvest loss and within the range of 11-27.4% for harvesting, threshing, drying and storage but a bit higher weight losses in Sub-Saharan Africa which is 12.2% (Ramatoulaye, 2010 and Rick Hodges *et al.*, 2014) respectively.



**Figure 4:** Percentage of post-harvest loss estimation at different steps.

#### 4.1.11 Factors aggravating post-harvest loss of rice and measures taken to minimize it

Farmers responded that they are aware of the rice post-harvest loss that occurs but, except for the loss at milling, they thought it is natural and take no measures to prevent or minimize the loss. According to the survey results, 100% of the respondents debunk that weather and manmade events aggravate the pre-and post-harvest loss. Surprisingly, they don't feel that they have lost part of their produce. This situation makes them to be reluctant to take actions that could help to reduce the post-harvest loss. Perhaps, that is why even the extension system tends to focus on the production aspect only. According to the Fogera district office of agriculture expert, the trainings and technical support are often addressed and high priority is given to mobilize farmers during the plowing and weeding part only except slight intervention of NGO on the post-harvest part.

## 4.2 Field data collection on ‘Tile plot of board’ method

### 4.2.1 Harvesting loss

On-farm harvesting losses of rice field during harvesting and stalk drying assessed and measured on five farmers’ fields, each measures 4x4m area on X-jigna variety with three replications. The rice plots were harvested at 18.84% of mean moisture content which is below the recommended harvesting MC of 20-25% (IRRI, 2013 a). According to this study, the mean harvesting loss of 3.04% recorded (Table 4). These results are nearly similar to those of El-Sharabasy (2007) in Egypt that the data obtained on total grain losses for traditional harvesting system of 3.88, 3.64, 3.52 and 3.35 % at different grain moisture contents of 19.64, 21.85, 23.76 and 25.91 %, respectively. These results are also similar to grain loss of 3.4% at maturity (Shakoor and Salim, 2005) and in the lower range of 3.03% to 12.05% (Ramatoulaye, 2010). On the other hand, this result is also nearly similar to 3.2% estimated by the farmers in the survey part.

**Table 4:** Harvesting loss at farmers’ field.

Variables	Mean	Std. deviation	Min	Max
N	5	5	5	5
Harvesting yield from the sample area (g)	22,116.00	5,986.20	18,195.00	32,477.00
Paddy loss collected from the sample area (g)	667.52	189.80	391.91	911.59
Percentage of loss	3.04	0.65	2.13	3.92
Moisture content at harvesting (%)	18.84	2.12	16.00	21.10

N: is sample population, Min is minimum and Max is maximum.

### 4.2.2 Threshing loss

Threshing loss of rice on five farmers threshing fields were assessed and measured the magnitude of losses encountered during oxen threshing. The scattered grains during the threshing process, leftover grains on the threshing field and undetached grains with the straw all carefully collected. Based on this field data collection, a mean loss of 3.84% recorded with a minimum and maximum of 2.78 and 5.85% respectively (Table 5). These findings nearly agree to 3.38% threshing loss recorded in China [www.fao.org/docrep /004 /AC301E](http://www.fao.org/docrep /004 /AC301E)



[/AC301e04.htm](#) But, higher than the mean value of 2.45% for bag beating method of panicle harvesting and lower than the mean value of 6.14% for “bambam” (a big locally made wooden box) threshing of sickle-harvested rice in Ghana (Ramatoulaye, 2010). These finding get support from those of (Hodges et al. (2014) where reported 3% threshing loss for cereal crops in Sub-Saharan African countries. On the other hand, this finding is higher than that of the survey findings of this study which is 2.4% estimated by the respondents.

**Table 5:** Threshing loss at the farmers’ field

<b>Variables</b>	<b>N</b>	<b>Mean</b>	<b>Std. deviation</b>	<b>Min</b>	<b>Max</b>
Total yield obtained from the threshing field (kg)	5	851.75	320.99	408.00	1271.65
MC at harvesting (%)	5	13.48	1.08	12.61	14.90
Percentage of loss in each threshing field	5	3.84	1.19	2.78	5.85

Where; MC is moisture content, N is sample population, Min is minimum and Max is maximum.

#### **4.2.3 Cleaning and drying loss**

Quantification of paddy rice loss during cleaning and drying was carried out by deploying experienced women. She took care of the cleaning and drying of 25 kg paddy rice in three replications for four hours and the scattered grains were collected and weighed. Finally, a mean loss of 1.11% was recorded which is somewhat less than the findings of 1.66% is drying loss reported by Ramatoulaye (2010) in Ghana. This may be due to the harvesting practice at lower moisture content (19%) which is lower than the recommended moisture content of 20-25%, due to stalk drying for 2-3 days and heaped for 15-20 days before threshing. As it is clearly known that drying loss is the lump sum of grains eaten by animals, scattered grains out of the drying and cleaning canvas and moisture losses hence, the paddy may not have too much moisture to lose during the drying and cleaning operations. On the other hand, this find is within the range of 1-5% drying and cleaning loss reported by NAS (1978) and complemented with the survey findings of this study reporting 1.19% for cleaning and drying loss.

**Table 6:** Cleaning and drying paddy rice loss.

<b>Variables</b>	<b>N</b>	<b>Mean</b>	<b>Std. deviation</b>	<b>Min</b>	<b>Max</b>
Initial weight of paddy rice (g)	3	25,000.00	0	25,000	25,000
Final weight of paddy rice (g)	3	24,566.67	115.47	24,500	24,700
Weight of collected grains that were scattered (g)	3	277.46	17.51	263.67	297.16
Percentage of loss	3	1.11	0.07	1.05	1.19

Where; N is number of samples, Std. deviation is standard deviation, Min is minimum and Max is maximum.

#### 4.2.4 Storage loss measurement

Three different storage materials (local storage, polypropylene bag and PICS (Purdue improved crop storage)) were evaluated under the farm gate condition. At the end of five months (150 days), Pest occurrence observations conducted in all deployed materials and no sign of weevil or any other pests were found. Finally, 1.33%, 0% and 3.47% of mean loss measured on local storage, PICS bag and polypropylene bags, respectively due to moisture loss and eaten by rats (Table 11). This finding is almost in line with rice storage loss in tropical savannah region 1.22% those reported by (APHLIS, 2014) with the local storage but, higher for the polypropylene bag finding (Table 11). Whereas, this finding quite lower than those reported losses ranging from 6.19% to 9.35% in two months' time (Ramatoulaye, 2010). This variations may be due to storage material difference, availability of pests where pest infestation were found in the Ramatoulaye finding but not in this study or may be the geographical locations where very high temperature variations occurred that affects the grain moisture content. Generally, this study finding revealed that use of PICS bag technology records zero loss, this is due to maintaining the initial grain moisture and absence of rat attack as compared to polypropylene bag and local storage where observed rat attack and moisture loss for PP bag and moisture loss for local storage.

**Table 7:** Weight and moisture loss of paddy over the storage time.

Storage materials	Loss in 75 days (%)	Loss in 150 days (%)	Initial moisture (0 time) (%)	Final moisture 150 days (%)
Local storage	0.53	1.33	12.9	12.01
PICS bag	0	0	12.9	12.9
Polypropylene bag	1.73	3.47	12.9	10.98

The local storage and PICS bag has shown a significant difference in their mean with polypropylene bag in weight loss at 2.5 and 5 months storage period, PICS bag and local storage has also shown a significant difference at 5 months' time only. Milling results of PICS bag with local storage and local storage with polypropylene has shown a significant difference while PICS bag with polypropylene bag has shown a highly significant difference. The grain moisture content has shown a significant difference on both in storage time and storage material.

**Table 8:** ANOVA table of storage loss on local storage, polypropylene bag and PICS bag

Source of variation	DF	SS	MS	Fcal
Treatment	2	0.92	0.46	11.5
Error	6	0.24	0.04	
Total	8	1.16		

CV%=0.81

#### 4.2.5 Paddy rice milling

##### 4.2.5.1 Milling efficiency of one-pass and two-pass milling machines

The milling efficiency of the two milling machines i.e. one-pass and two-pass, see the picture in annex 6) were measured. The mean milling recovery of 67.86% and 76.8% were recorded for one-pass and two-pass milling machines, respectively at 12.2% moisture content (Table 7) falling within the range of 12-13% moisture (Terry *et al.*, 2011). The milling moisture content was lower than that of 14%, which is recommended as a suitable milling moisture content (APHLIS, 2014), and IRRI, <http://www.knowledgebank.irri.org/step-by-step-production/postharvest/milling>). The recorded milling recovery rates of the two machines were below the

ideal recovery rate which is 20% husk, 8-10% bran and 68-70% white rice with a head rice recovery of over 70% [([www.bagworldwide.com/portfolio-view/rice-processing](http://www.bagworldwide.com/portfolio-view/rice-processing) and Terry *et al.* (2011)]. The findings lend support to the findings of (Alizadeh and Allameh, 2013), 67.00% and 67.72% milling yield for two different harvesting methods in Iran. Thus, present findings are somewhat lower than 69.77% of the mean recovery rate reported by (Salim. and Sagar, 2003) in Pakistan and higher than 63.33% and 67.3% for one-pass and two-pass milling respectively found by Ramatoulaye (2010) in Ghana. Also those results nearly similar to the survey findings of 69% and 68.33% for polished rice (one-pass) milling machine result Yenew (2015) and Zewdu (2016) but, higher than the findings of Zewdu (2016) for the two-pass milling machine results of 73.8% in Ethiopia, these variations may be due to the efficiency of milling machine operators. Generally, when compared to the two milling machines milling Result employed in this study, a mean of 5.87% of milling loss was recorded in the one-pass milling machine which is within the range of 5-30% milling loss recorded for South East Asia (Hodges et al., 2011) and 2-10% for West Africa (FAO, 2007).

**Table 9:** Milling results of differently processed rice materials and different millers.

<b>Variables</b>	<b>Paddy rice weight (kg)</b>	<b>Polished/de-husked rice weight (kg)</b>	<b>MC (%)</b>	<b>Recovery rate (%)</b>
One-pass milling machine (raw paddy)	75	50.90	12.20	67.86
Two-pass milling machine (raw paddy)	75	57.60	12.20	76.80
Two-pass milling machine (parboiled)	75	60.10	14.00	80.13
M1 (one pass machine)	75	50.20	12.20	66.93
M2 (one pass machine)	75	51.60	12.20	68.80

Where; MC is moisture content, M1 is miller one and M2 is miller two.

#### **4.2.5.2 Milling recovery rate of raw paddy and parboiled rice on two-pass milling**

The recovery rates of raw paddy and parboiled rice were measured using two-pass rice milling machine and the results revealed 76.8% and 80.13% of processed rice respectively (Table 11).

These findings are somewhat higher than the survey findings of 76% (Yenenew, 2015) and 78% milling results for parboiled rice (Zewdu *et al.*, 2013), but lower than 84% for raw paddy (Zewdu *et al.*, 2013), which is exceptional for X-jigna variety only (Table 12). These may be due to the difference parboiling procedures followed in this study (soaked for 14 hours in cold water, steamed for 4hrs using electric boiler and dried for 5 days under shade). Which is different from what Zewdu followed (soaked in 80-90°C hot water until the mix temperature dropped to 60-65°C, steamed for 4 hours and dried under direct sun) and the milling machine performance and agronomic management difference where Zewdu used from the research station and this study were conducted by the farmers produce. According to James (1983) parboiling is done to improve the milling recovery of paddy and this logic has come true in this study too as it has shown 3.33% recovery advantage over the raw paddy milling.

**Table 10:** Effect of parboiling on percentage of milling recovery

Heat treatment	Variety				mean
	Gumara	Kokit	Tigabe	X-jigna	
Parboiled	88.73	81.83	87.51	77.80	83.97
Raw rice	72.67	81.83	79.67	84.33	79.50
Mean	80.70	81.58	83.59	81.07	
LSD <sub>0.05</sub>			5.12		2.57

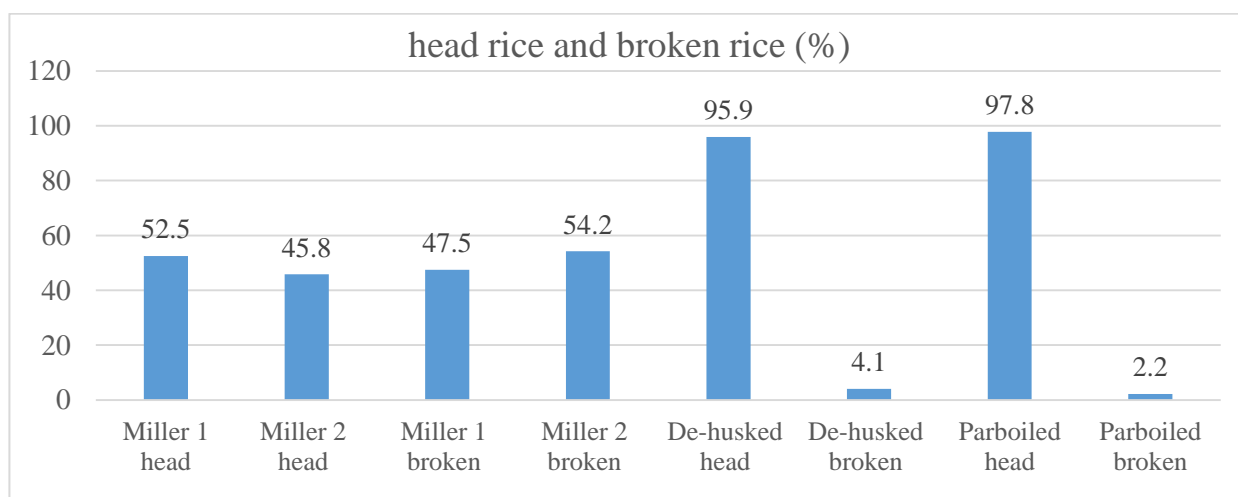
Source: Zewdu et al. (2013) Effect of parboiling treatment on the milling quality of selected rice varieties

#### 4.2.5.3 Comparison of the milling efficiency of different millers

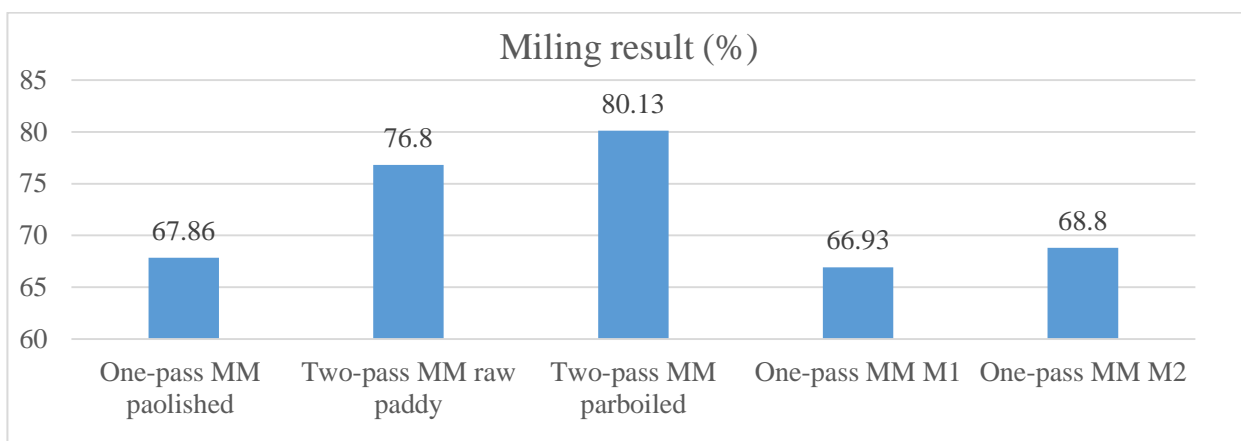
The milling efficiency of the two miller technicians' designated as miller one and miller two, respectively was assessed by using one-pass milling machines. The milling results revealed 66.93% milling efficiency for miller one and 68.8% for miller two (Table 11), this finding debunk a potential loss of 1.78% due to the capacity and the skill of milling technicians. These findings are in complement with the findings of 66.8% to 68.53% for two different millers (Ramatoulaye, 2010) which is about 1.73% milling yield difference due to the technicians.

#### 4.2.5.4 Recovery of head rice

The head rice recovery results of raw rice, parboiled rice and polished rice resulting from miller one and millers two revealed head rice and broken rice recoveries to the extent of 95.9% and 4.1%, 97.8% and 2.2% and 49.15% and 50.85%, respectively (Fig 4). The polished rice findings are quite lower than the results of polished head rice and broken rice results as compared to the findings of 76.16% and 23.85% head and broken rice for the indirect harvesting and 79.04% and 20.96% head rice and broken rice for the direct one respectively in Iran (Alizadeh and Allameh, 2013). This significant difference may be due to the farmers over-drying culture of paddy rice during harvesting and milling (15-19 MC at harvesting and 12.2% MC at milling, which is quite lower than the recommended harvesting and milling moisture content of 20-15%MC and 14% MC respectively). The other possible reasons may be that Alizadeh and Allameh conducted their study under laboratory condition whereas, this study conducted under the private-owned operational milling machines or may be due to variety differences. However, on the other hand head rice of parboiled rice is almost in line with 99.8% head rice yield (IRRI, 1983)



**Figure 5:** Head rice and broken rice results of different millers, products and different milling machines



Where; MM is milling machine, MM M1 is milling machine miller1& MM M2 is milling machine miller2

**Figure 6:** Milling result of different machines and rice product types

#### 4.2.5.5 Quantification and significance of post-harvest losses

The result of this study revealed that, the amount of losses at each step is quite considerable to devise an intervention plan. According to the Fogera office of agriculture (2016) 1.59 million quintals of paddy rice were produced (Annex 5) hence, according to this finding about **244,209** quintals of paddy rice could not reach to the consumers table in the study area alone annually which is more than a monetary value of 207,557,650 ETB or \$ 9.4 million. This could be a potential food supply for 1.44 million people for one month. Bearing in mind the aforementioned reality, it is too simple to estimate the post-harvest loss significance at regional and national level in securing the household food grain demand.

**Table 11:** Ranges of rice post-harvest losses at each steps

Post-harvest activities	Minimum loss (%)	Maximum loss (%)	Mean loss (%)
Harvesting loss	1.96	5.75	3.04
Threshing loss	2.78	5.85	3.84
Cleaning and drying loss	1.05	1.19	1.11
Storage loss	1.2	4.4	2.4
Milling loss	3.3	9.87	5.87
Cumulative loss	10.29	27.06	16.26

Where; 1 quintal=100kg.

## **CHAPTER: 5**

### **5. SUMMARY, CONCLUSION AND RECOMMENDATIONS**

#### **5.1 Summary**

Rice is produced in a wide range of locations and under a variety of climatic conditions. It is known that one-third of all food produced for human consumption worldwide is lost or wasted which translates into 1.3 billion tones, worth nearly one trillion US dollars. Reduction of these losses would increase the amount of food available for human consumption and enhance global food security.

This research was conducted in Fogera district, which is located in South Gondar Administration Zone of Amhara region, Ethiopia in the year 2016 which is the major rice belt in the country. The main objective of the study was to determine and quantify the post-harvest losses of rice from harvesting to milling.

The study was conducted in two phases; household survey and field survey for harvesting, threshing and on cleaning and drying, storage and milling. The study Kebele (peasant association) was selected using purposive sampling technique and the 70 farm households were selected randomly. Primary data pertaining to 2016 cropping season were collected from sample respondents using a semi-structured questionnaire with the help of enumerators and field survey data with respect to harvesting, threshing, cleaning and drying, storage and milling data were also recorded. Focus group discussion and key informant interview was conducted/

Statistical Package for Social Science (SPSS) version 20.0 (2011) was employed to analyze the data. Simple descriptive statistics such as mean, standard deviation, frequency and percentages were used for the household surveyed, field surveyed and experimental data collected from storage and the analyzed data presented using tables and figure.

Based on the results of this survey from the total 70 interviewed households engaged in rice production were 78% male and 22% female households respectively with a mean age of 40.67 years ranging from 21 years to 68 years. According to this survey, the average family size is



5.8 and the educational level of the respondents reflected 47.1% as unable to read and write, 7.1% able to read and write, whereas the rest attend education at different levels.

The mean land holding size of sample respondents was 1.00 ha and 37% of the respondents rented additional land with an average size of 0.4ha for rice. The average rice productivity was 41.51 quintals per ha. Interestingly 72.8% of the respondents had more than 15 years of rice production experience.

According to this survey, 100% of the respondents believed on the existence of PHL and in this regard, 80% of the respondents argued that there exists a loss at harvesting, 68.6% at threshing, 59% due to birds during stalk drying, 8.3% at grain drying stage, and 64.3% of them at storage. Milling was one of the significantly addressed issues as the major PHL activity for which 94.3% of the respondents agreed. Among the storage loss causes, 59.8% respondents identified rat as the main causes for rice loss, 25.8% weevil and the rest 14.45 said domestic animals.

Farmers dominantly store their paddy rice using ‘Gotta/Gottera’ and polypropylene (PP) bags and 94.3% of the respondents store rice using both storage materials, although 98.6% of them agreed that PP bags causes the highest loss due to easy loss of paddy moisture as compared to the local storage material. According to the respondents, about 50% of the produce is reserved for market with the possibility of storing six to nine months whereas, the paddy for home consumption is stored up to the next harvest.

The farmers choose the two-pass milling machine for home consumption and one-pass machines for market purpose. This is due to the market requirement of white rice and they prefer the brown rice for home consumption for ‘enjera’ quality and high recovery rate. In relation to milling, 63.2% of the respondents believed that early season milling has high breakage level while the rest 36.87% argued that the highest breakage occurred at late milling period. All the respondents argued that the efficiency of milling technicians and behavior affect the recovery rate of paddy milling.

The sample respondents were estimated the amount of losses occurring at each steps and milling losses were identified as the biggest PHL and the drying and cleaning as the lowest PHL with 5.7% and 1.19%, respectively and a total of 14.87% loss was estimated.

In addition to the survey, sample data were taken to measure the losses at harvesting, threshing, drying and cleaning, and at storage using three different storage materials and milling. The result revealed a mean of 3.04% for harvesting, 3.84% for threshing, 1.11% for cleaning and drying, 2.4% for storage and 5.87% for milling loss. The recovery rates of raw paddy were 67.86% and 76.8% for one-pass and two-pass, 80.13% and 76.8%, recovery on two-pass for parboiled and raw paddy was recorded respectively. The efficiency of two millers was also measured and a difference of 1.78% milling yield variation recorded. The head rice yield of different machines and products were also measured and 95.9% and 97.8% of head rice were recorded for brown and parboiled rice using two-pass milling machine, respectively and 49.15% head rice was found for white rice using one-pass milling machine. Farmers harvest rice at low moisture and end up with high milling loss and breakage.

Farmers are aware of the PHL although they take no measures to minimize it hence, about 10.29-27% loss were recorded. Two pass milling machine and parboiling improve the recovery of milling and PICS bag has the highest milling recovery and the lowest loss. Finally improvement of the extension support on PH system, introducing small-scale PH technologies, promotion of PICS bag and two-pass milling machine and further PH studies are recommended.

## **5.2 Conclusions**

Farmers harvest the rice comparatively at lower moisture content and the stalk and heaping is left for a period of times. This activity causes the paddy to dry over and ends up with very high breakage level during milling. However, the recovery rate is not significantly lower than those found in other countries due to the short and thick nature of X-Jigna variety that resists the abrasion of the machine.

Farmers are fully aware of the post-harvest loss existence at each steps although they believed that it is but natural and take no measures to avoid or minimize the loss. This is due to the weak

extension support to post-harvest management, as clearly indicated by the fact that the focus of government extension support is for the pre-harvest operations only.

The result of this study, both the survey and practical field data collection, revealed that the post-harvest loss is encountered at each steps ranging 10.29 to 27.06% whereas, milling loss of one-pass machine takes the lion share of all the losses. This is due to the fact that the millers tended to tighten up the roller to carefully scratch the bran layers to whiten the rice due to the market requirement of white rice, whereas, farmers use two-pass milling for home consumption on account of its test and quality of brown rice product which is about 50% of the total production.

The observed storage materials has shown a clear performance difference on account of storage loss, moisture conservation and milling recovery performance with a mean of 2.2% loss difference (Table 11), that should be considered during storage material selection

The millers' skill is another contributing factor for milling loss and high breakage level with 1.78% variation of recovery rate observed between two millers. Not surprisingly, this figure becomes even worst at beginners or fresh technicians.

Importantly, according to the results of this study, it is possible to maximize the recovery rate of paddy rice through parboiled technique and by using the two-pass milling machines up to 12.24%, rather using the one-pass milling machines even though the cost and time of parboiling process is higher.

### **5.3 Recommendations**

Based on the findings of this study, the following recommendations are suggested:

Improvement in the extension and capacity building: The capacity building and extension support has to address the post-harvest handling management in line with the pre-harvest extension support. In-depth and frequent training has to be accorded to farmers and extension agents with full post-harvest package manual to raise the extension agent and producers' awareness on post-harvest handling with a clear demonstration of economic significance.

Introducing small-scale post-harvest technologies: It is vital to introduce and promote the small scale technologies of harvesting and threshing and the moisture tester technology has to be introduced to improve the quality of rice and to minimize the post-harvest loss.

Promote two-pass milling machine: The findings of this study revealed that rice breakage was the major problem because of the obsolete one-pass milling machines. Hence the two-pass milling machines has to widely promoted for its better recovery rate and low breakage level. from the processors side and on the other hand, the consumers' awareness has to be raised on the nutritional value of brown rice over white rice.

Training and technical support has to be given to millers on the nature of paddy rice, maintenance and operational management of milling machines and general implications of losses nationally.

PICS has to be promoted widely for the farmers with a clear evidence of showing the economic return rates of storage loss minimization and milling performance and in the meantime the local storage materials has to be improved as it has better performance than the polypropylene bag.

Further post-harvest studies have to be conducted on: appropriate harvesting and threshing period, effect of soil nutrition management on the milling performance of paddy, appropriate milling moisture content, economic significance of post-harvest loss on the smallholder farmers and losses in the other part of the post-harvest chain like transportation and warehouse losses.

## REFERENCES

- ADM Institute for the Prevention of Postharvest Losses (2015). (Archer Daniels Midland) Partnering with the World. Annual Report. Available at: [http://postharvestinstitute.illinois.edu/postharvest\\_institute@illinois.edu](http://postharvestinstitute.illinois.edu/postharvest_institute@illinois.edu).
- Alizadeh M.R. and Allameh A. (2013). Evaluating rice losses in various harvesting practices. International Research Journal of Applied and Basic Sciences © 2013 Available online at [www.irjabs.com](http://www.irjabs.com) ISSN 2251-838X / Vol, 4 (4): 894-901 Science Explorer Publications. Agricultural Engineering Department, Rice Research Institute of Iran, Rasht, Iran.
- Anonymous (n.d) post-harvest losses: discovering the full story. Overview of the Phenomenon of Losses during the Post-harvest System. Website ([www.fao.org/doc\\_rep/004/AC301E/AC301e04.htm](http://www.fao.org/doc_rep/004/AC301E/AC301e04.htm)). Accessed April 7, 2017
- Anonymous (n.d) milling and quality: post production step-by-step/production or post-harvest/milling and processing. Website (<http://www.knowledgebank.irri.org/step-by-step-production/postharvest/milling>). Accessed April 9, 2017
- APHLIS (2014). (African Post Harvest Loss Information System). Hodges R., Bernard M. and Rembold F.— Postharvest cereal losses in Sub-Saharan Africa, their estimation, assessment and reduction: European Commission Joint Research Centre. Institute for Environment and Sustainability
- Appiah F., Guisse R. and Dartey P. K. A. (2011). Post-harvest losses of rice from harvesting to milling in Ghana. *Journal of Stored Products and Postharvest Research*, Vol. 2(4): 64–71. Department of Horticulture, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana. Available at: <http://www.academicjournals.org/JSPPR>.
- Basavaraja H., S.B. Mahajanashetti and Naveen C. U. (2007). Economic Analysis of Post-harvest Losses in Food Grains in India: A Case Study of Karnataka.
- Buzby J. C., and Jeffrey H. (2012). “Total and per capita value of food loss in the United States.” *Food Policy* 37: 561-570.
- CGIAR (2013 a). (Consultative Group on International Agricultural Research). Postharvest loss reduction—a significant focus of CGIAR research: *News from the CGIAR Consortium*. Available at: (<http://www.cgiar.org/consortium-news/categories/consortium-news/>), (November 20/2013). Accessed 27<sup>th</sup> January 2016.

- CGIAR (2013 b). (Consultative Group on International Agricultural Research). Rice Almanac fourth edition. International year of rice 2004: Rice and human nutrition. Available at [www.fao.org/rice2004/en/f-sheet/factsheet3.pdf](http://www.fao.org/rice2004/en/f-sheet/factsheet3.pdf)
- CSA (2015) (central statistical agency). Agricultural sample survey 2014/2015 (2007 E.C.) production season volume I, report on area and production of major crops.
- CSA (2016) the federal democratic republic of Ethiopia central statistical agency agricultural sample survey 2015/2016 (2008 E.C.), volume i: report on area and production of major crops (private peasant holdings, ‘meher’ season).
- CTA (2012). (Technical Centre for Agricultural and Rural Cooperation). Policy brief: Going to waste – missed opportunities in the battle to improve food security. No 7. Organized by CTA, the European Commission (DG DEVCO), the Secretariat of the ACP Group of States and Concord, the European NGO Confederation for Relief and Development. Brussels, June 2012. Available at: <http://brusselsbriefings.net>.
- El Hissewy A.A. (1999). A Study on the Yield Losses of Rice Due To the Use of Traditional Rice Mills and Their Effect on the National Rice Production in Egypt. Agricultural Research Center & Academy of Science & Technology (in press).
- El-Sharabasy M. M. A. (2007). Total grain losses, energy and cost requirements for harvesting rice crop mechanically in delta Egypt. *Misr J. Ag. Eng.*, 24(1): 1-17
- EUCORD (2012). (European Union Cooperation for Rural Development). Rice Sector Development in East Africa. A desk study prepared for the Common Fund for Commodities.
- FAO (2007). Post-harvest loss compendium—database of information on PHL for different crop types. See [www.fao.org/inpho](http://www.fao.org/inpho).
- FAO (2008). (Food and Agricultural Organization of the United Nations). Rice Marketing Monitor. European Commission’s Evaluation of the Impact of Rice Sector Reforms. [[www.agritrade.cta.int](http://www.agritrade.cta.int)>Home>Commodities>Rice sector][Accessed 6th April 2010]
- FAO (2011). (Food and Agricultural Organization of the United Nations). Global Food Losses and Food Waste. by Cederberg C., Gustavsson J., Meybeck A., van Otterdijk R. & Sonesson U. Available at: <http://tinyurl.com/ca84yux>
- FAO, (2014). Rice market monitor. Volume XVII, issue No.1
- FAO (2015). (Food and Agriculture Organization of the United Nations). Food wastage footprint& Climate Change. 4 pager Fact sheet.

- FAO (1980). (Food and Agriculture Organization of the United Nations). Assessment and Collection of Data on Post-harvest Food Grain Losses, FAO Economic and Social Development Paper 13. Rome.
- FAOSTAT (2010). Production quantities of Rice, paddy in Africa, Food and agricultural organisation of the united nation.
- Fox T. and Fimeche C. (2103). Global food Waste Not, Want Not. IMechE. England and Wales.
- Firouzi S., Alizadeh M. R and Minaei S. (2010). Effect of the size of perforated screen and blade-rotor clearance on the performance of Engleberg rice whitener. *African J Agric Res.* 5(9): 941-946.
- Gray R. (1962). A report on the conference. *Journal of African History* 3: 175–191.
- Grolleaud M. (2002). Post-harvest losses: discovering the full story. Overview of the phenomenon of losses during the post-harvest system. Rome, Italy: FAO, Agro Industries and Post-Harvest Management Service.
- Grolleaud, M. (2001). Post-harvest losses: Discovering the full story overview of the phenomenon of losses during the post-harvest system. Rome, FAO.
- Gustavsson J., Cederberg C., Sonesson U., van Otterdijk R. and Meybeck A. (2011). Global Food Losses and Food Waste: Extent Causes and Prevention. Rome, Food and Agriculture Organization (FAO) of the United Nations.
- Harris L. Kenton and Lindblad J. Carl (1976). Postharvest grain loss assessment methods. A Manual of Methods for the Evaluation of Postharvest Losses.
- Hodges R.J., Buzby J.C and Bennett B. (2011). Postharvest losses and waste in developed and less developed countries: opportunities to improve resource use. *Journal of Agricultural Science*, 2011 (149), 37-45. © Cambridge University Press 2010.
- Hodges R. H. (n.d). Postharvest weight loss estimates for cereal supply calculations in East and Southern Africa. Available at: <http://www.phlosses.net/downloads/Postharvest-lossesreport.pdf>. pdf/http://www.phlosses.net/downloads/Postharvestlosses-report.pdf.
- IRRI (1983). (International Rice Research Institute). Paddy Rice Postharvest industry in Developing Countries: Technical Handbook. International rice research institute los baños, laguna, philippines p.o. box 933, manila, Philippines.
- IRRI (2009). Rice Policy- World Rice Statistics (WRS). Available at: <http://www.irri.org/science/ricestat>. Accessed January 9, 2016.

- IRRI (2013 a). Rice Harvesting Training Manual. Copyright 2013. The International Rice Research Institute. Available at: <http://www.Knowledge bank .irri.org /images/ docs / training-manual-harvesting.pdf>. Accessed January 9, 2016.
- IRRI (2013 b). Paddy drying training manual. Copyright 2013. The International Rice Research Institute. Available at: <http://www. knowledgebank.irri.org/step-by-step-production/ postharvest/drying>. Accessed January 9, 2016.
- IRRI (2013 c). Grain Storage and Pest Management training manual. Copyright 2013. The International Rice Research Institute. Available at: <http://www.knowledgebank. irri. Org / images/docs/training-manual-grain-storage.pdf>. Accessed January 9, 2016.
- IRRI (2013 d). Rice milling and processing manual. Copyright 2013. The International Rice Research Institute. Agricultural engineering unit Available at: <http://www.knowledge bank.irri.org/step-by-step-production/postharvest/ milling>. Accessed January 9, 2016.
- IRRI (n.d). Milling and quality. Rice Knowledge Bank <http://www.knowledgebank.irri.org /stepbystepproduction/postharvest/milling/millingandquality?tmpl=componentcategory&print=1> accessed February 2016.
- Jaspreet, Aulakh and Anita Regmi (2013). post-harvest food losses estimation- development of consistent methodology.
- Julian P., Barthel M. and Sarah M. (2010). Food waste within food supply chains: quantification and potential for change to 2050. *Resource Futures, Bristol, UK Waste and Resources Action Programme, Banbury, UK Isis Innovation Ltd, Oxford, UK*.
- Kader, A.A. and R.S. Rolle. 2004. “The Role of Post-harvest Management in Assuring the Quality and Safety Horticultural Crops”. Food and Agriculture Organization. Agricultural Services Bulletin.
- Kader, A.A. 2005. “Increasing food availability by reducing postharvest losses of fresh produce.” *Acta Horticulture* 682:2169-2176.
- Lantin R. (1997). Rice post-harvest operation. Achapter for the post-harvest compendium within Information Network on Post-harvest operations (INPhO). Available at: [www.fao.org/inpho/index-e.htm](http://www.fao.org/inpho/index-e.htm).
- Liang L. (1993). China’s post-harvest grain losses and the means of their reduction and elimination. *Jingji dili (Econ. Geogr.)* 1, 92–96. Penis nerd
- LRAN (2008). (Land Action Research Network). Available at: [www.g24.org/mitta0908.pdf](http://www.g24.org/mitta0908.pdf)



- Mejía D.J. (2002). An overview of rice post-harvest technology: use of small metallic silos for minimizing losses. Agricultural Industries Officer, Agricultural and Food Engineering Technologies Service, FAO, Rome, Italy.
- Mekuria Yimer. (2015). Women's participation in rice production: the case of fogera woreda, south gondar administrative zone of amhara national regional state, Ethiopia. M.Sc. Thesis, Bahir Dar University Bahir Dar Ethiopia.
- Mundial B. (2008). Double Jeopardy: responding to high food and fuel prices. Cumbre Hokkaido-Toyako.
- NAS (1978). (National Academy of Science). Postharvest Food Losses in Developing Countries. *Board on Science and Technology for International Development Commission on International Relations National Research Council*. Washington, D.C. 1978. Available at <http://books.google.ccom/>
- National Geography news (2014). Future of food, one-third of food is lost or wasted: what can be done? By Elizabeth Royte. <http://news.nationalgeographic.com/news/2014/10/141013-food-waste-national-security-environmentscience-ngfood.html>.
- Nayar N.M. (2010). Origin of African rice from Asian rice. Department of Botany, University of Kerala, Kariavattom 695 581, Trivandrum, Kerala, India. Second Africa Rice Congress, Bamako, Mali, 22–26 March 2010: Innovation and Partnerships to Realize Africa's Rice Potential. Theme 1: Rice genetic diversity and improvement.
- Ngatia C. M. and Kimondo, M. (2011) Comparison of three methods of weight loss determination on maize stored in two farmer environments under natural infestation. KARI – Kabete, Post harvest research, NARL. P. O. Box 14733-00800 Nairobi, Kenya.
- NRI (1991). (Natural Resources Institute). Post-harvest discoloration of cereal grains. Report on operational Programmes: 1989-91: 256-258. Chatham Maritime, Chatham, Kent, UK.
- NRRDSE (2009). (National Rice Research and Development Strategy of Ethiopia). The federal democratic republics of Ethiopia Ministry of Agriculture and Rural Development.
- Porteres R. (1962). Primary cradles of agriculture in the African continent. *Journal of African History* 3: 195–210.
- Porteres R. (1976). African cereals. Pp. 409–452. In: Harlan JR and De Wet JMJ ed. *Origins of African Plant Domestication*. Mouton, The Hague.
- Ramatoulaye G. (2010). Post-harvest losses of rice (*oriza spp*) from harvesting to milling: a case study in besease and nobewam in the ejisu juabeng district in the ashanti region of

- Ghana. MSc thesis, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana.
- Ren-Yong, Chi, Zhuge Gen-Zhang & Wan Shan-Yang. 1990. Loss assessments and factor-finding analysis of grain post-production systems in China. Proceedings of the Thirteenth ASIAN Seminar on Grain.
- Yong R., Chi, Gen-Zhang Z. and Shan-Yang W. (1990). Loss assessments and factor-finding analysis of grain post-production systems in China. Proceedings of the Thirteenth ASIAN Seminar on Grain Postharvest Technology, Brunei Darussalam, 4-7 Sept. 1990. Pp. 370-392. In Naewbanij, J.O. ed. ASIAN grain post-harvest programme. Bangkok, Thailand.
- Rice milling: The rice kernel composition [www.bagworldwide.com/portfolio-view/rice-processing](http://www.bagworldwide.com/portfolio-view/rice-processing). Accessed April 11, 2017.
- Salim M. and Sagar MA. 2003. Milling quality of rice. *Pakistan Journal of Food Sciences*.
- Shahi B.B. (1985). Potential Rice Varieties for East Africa. In International Rice Research Institute. Rice Improvement in Eastern and Central Africa, Proceedings of the International Rice Workshop, April 9-19 1984, Lusaka, Zambia.
- Shakur A. and Salim M. (2005). Rice harvesting and threshing Postharvest Management Programme, \*National Coordinator, Rice, National Agricultural Research Center, Islamabad. *PAK J FOOD SCI* 2005, 15(1-2): 45-52.
- Taiwo A. and Bart-Plange A. (2016). Factors responsible for post-harvest losses and their effects on rice producing farmers: a case study of Afife and Aveyime rice production in the Volta region of Ghana. *International Research Journal of Engineering and Technology (IRJET)* e-ISSN: 2395 -0056 Volume: 03 Issue: 04 | Apr-2016 [www.irjet.net](http://www.irjet.net) p-ISSN: 2395-0072.
- Terry J. Siebenmorgen, Paul A., Counce and Charles E.W. (2011). Factors Affecting Rice Milling Quality, Agriculture and natural resource: University of Arkansas, United States Department of Agriculture, and County Governments Cooperating, FSA2164
- Trostle R. (2010). Global Agricultural Supply and Demand: Factors Contributing to the Recent Increase in Food Commodity Prices. (Rev. DIANE Publishing.)
- Tyler P. S. (1982). Misconception of food losses. Tokyo, Japan: United Nations University Press.

- WARDA (2005) (West Africa Rice Development Association) Rice, a strategic crop for Food Security and Poverty Alleviation. Available at: [www2.slu.se/cigar/CGIAR\\_WARDAppt](http://www2.slu.se/cigar/CGIAR_WARDAppt)
- WARDA (2008) (West Africa Rice Development Association). Annual Report. Cotonou, Benin Available at: [www.warda.org/warda/impactpub](http://www.warda.org/warda/impactpub)
- Yenenw Bezabih (2015). Rice value chain analysis in amhara region: the case of libokemkem district, Ethiopia. MSc. thesis, Bahir Dar University Bahir Dar Ethiopia.
- Zewdu Ayalew, Abebe Fanta and Solomon Abera (2013). Effect of Parboiling Treatment on the Milling Quality of Selected Rice Varieties. Amhara Regional Agricultural Research Institute, P.O.Box 133, Ethiopia Haramaya University, East Harerge, Ethiopia: *Journal of Postharvest Technology 01 (01): 060-068, October' 2013* [www.jpht.info](http://www.jpht.info)
- Zewdu Ayalew (2016). Performance testing of three rice mills and their effect on important rice varieties adapted in Ethiopian rice fields: Rwanda Agriculture Board (RAB) *palgo journal of agriculture, issn 2476-8359 Volume 3 Issue 3, June 2016. Page 156 – 165* <http://www.palgojournals.org/PJA/Index.htm>

## APPENDICES

### Appendix 1: survey questionnaires and focus group discussion check list

#### A survey questionnaire developed to study “Studies on the Assessment of Post-harvest Loss of Rice from Harvesting to Milling in Fogera Districts of Amhara Region, Ethiopia”

**Introduction:** The purpose of this study is to learn, assess and be aware of rice farmers existing situation of rice **post-harvest losses and management from harvesting to milling**. So your answers would be very much helpful and vital to make these research results meaningful. Therefore, please speak freely and give honest answers. The data will not be shared with anybody and so be assured of the confidentiality of any information you provide.

#### Demographic profile

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##### General

- Date of interview: \_\_\_\_\_ Code: \_\_\_\_\_
  - Name of Interviewer: \_\_\_\_\_
  - Name of supervisor: \_\_\_\_\_
- 

1. Name of respondent \_\_\_\_\_ age \_\_\_\_\_ sex \_\_\_\_\_
2. Marital Status: (A). Unmarried, (B). Married, (C). Divorced, (D). Widowed,
3. Family HH Size: Female \_\_\_\_\_ Male \_\_\_\_\_ Total \_\_\_\_\_
4. What is the size of your farm land? (A). 0.1-.25ha, (B). >0.25-0.5ha, (C). >0.5-1ha, (D). >1-1.5ha, (E). >1.5ha
5. Do you rent land for rice? (A). Yes, (B). No
6. If yes for Q5 how much area of land? \_\_\_\_\_ how many quintals do you able to harvest? \_\_\_\_\_
7. Educational status: (A). Unable to read and write, (B). Able to read and write, (C). Primary first cycle 1-4, (D). Primary Secondary cycle 5-8, (E). Secondary school 9-10, (F) Preparatory 11-12, (G). Above 12
8. How long have you been growing rice? (A). 5-9, (B). 10-14, (C). 15-19, (D). 20 or above

9. How much area of land allocated for rice in hectare? \_\_\_\_\_, how many quintals did you get? \_\_\_\_\_
10. What are the practices/steps you go for during harvesting to processing (please mention step-by-step)  
a. \_\_\_\_\_ b. \_\_\_\_\_ c. \_\_\_\_\_ d. \_\_\_\_\_ e. \_\_\_\_\_ f. \_\_\_\_\_ g. \_\_\_\_\_ h. \_\_\_\_\_
11. Do you experience pre and post-harvest loss in rice? (A). Yes, (B). No
12. If yes for Q10, is nutrient shortage is a causes for pre-harvest loss of rice? (A). Yes (B). No
13. If yes for Q10, is water shortage is a causes for pre-harvest loss of rice? (A). Yes (B). No
14. If yes for Q10, is pest and disease is a causes for pre-harvest loss of rice? (A). Yes (B). No
15. If yes for Q10, is weed is a causes for pre-harvest loss of rice? (A). Yes (B). No
16. If yes for Q10, is icefall is a causes for pre-harvest loss of rice? (A). Yes (B). No
17. If yes for Q10, is late rain is a causes for pre-harvest loss of rice? (A). Yes (B). No
18. If yes for Q10, is bird is a causes for pre-harvest loss of rice? (A). Yes (B). No
19. If yes for Q10, is harvesting is a causes for pot-harvest loss of rice? (A). Yes (B). No
20. If yes for Q10, is threshing is a causes for pot-harvest loss of rice? (A). Yes (B). No
21. If yes for Q10, is over drying is a causes for pot-harvest loss of rice? (A). Yes (B). No
22. If yes for Q10, is unwell prepared threshing field is a causes for pot-harvest loss of rice? (A). Yes (B). No
23. If yes for Q10, is the quality or type milling machine is a causes for pot-harvest loss of rice? (A). Yes (B). No
24. If yes for Q10, is bird or animal is a causes for pot-harvest loss of rice? (A). Yes (B). No
25. If yes for Q10, is storage is a causes for pot-harvest loss of rice? (A). Yes (B). No
26. How do you judge the timing (maturity) of rice harvesting? (A). By looking into the panicle color, (B). By using moisture tester, (C). Others please mention it \_\_\_\_\_
27. How many percent of rice loss could occur at harvesting? % \_\_\_\_\_
28. How many percent of rice loss could occur at threshing? % \_\_\_\_\_
29. How many percent of rice loss could occur at grain drying? % \_\_\_\_\_
30. How many percent of rice loss could occur at storage? % \_\_\_\_\_
31. How many percent of rice loss could occur at milling? % \_\_\_\_\_

32. Is there any seasonal/climatic/ factor(s) that aggravates the pre and post-harvest loss rice? (A). Yes, (B). No. if yes, please mention them? (A).\_\_\_\_\_ (B). \_\_\_\_\_ (C). \_\_\_\_\_ (D). \_\_\_\_\_
33. What are the tools or machines used to harvest your rice field?  
\_\_\_\_\_
34. Do you dry the stalks? (A). Yes, (B). No, if yes, for how long \_\_\_\_\_days. For how long the heaping will stay in the field. \_\_\_\_\_
35. How do you thresh the rice? (A). Using oxen, (B). Using stick, (C). Using machine, (D). others \_\_\_\_\_
36. Where do you clean the rice? (A). At the threshing field, (B). At home, (C). At the processing center
37. Do you dry the grain after threshing? (A). Yes, (B). No, if no, why?  
\_\_\_\_\_
38. How do you store rice? (A). Using polybag, (B). Using locally made materials/gotta/, (C). Using grain pro/PICS bag, (D). If others specify\_\_\_\_\_
39. For how long do you store rice? (A). Three months, (B). Six months, (C). Nine months, (D) One year, (E). > One year
40. For what purpose do you produce rice? (A). For consumption only, (B). For marketing only, (C). For both
41. How much of the produce will go to market? (A). <20%, (B). 21-30%, (C). 31-40%, (D). 41-50%, (E). >51%
42. What are the major causes of rice loss during storage? (A). Weevil, (B). Rat, (C). Home animals
43. Have you seen a loss difference among different materials used for storage? (A). Yes, (B). No, which storage material cause the highest loss to occur?  
\_\_\_\_\_
44. Where do you mill your rice? (A). At cooperative, (B). At private millers, (C). if others specify\_\_\_\_\_
45. Did you clean the paddy rice before taking it for milling? (A). Yes, (B). No
46. Do you have a machine preference for milling for both marketing and consumption? (A). Yes, (B). No. why? \_\_\_\_\_

47. Do you think there is a loss difference between the two different milling machines? (A). Yes, (B). No
48. Can you guess the loss rate of two different machines in %? (A). SB30 \_\_\_\_\_ (B). N70 \_\_\_\_\_
49. Have you seen the breakage and loss level difference based on the milling period? (early and late milling) (A). Yes, (B). No
50. If yes for Q 40 when does will occur the highest loss and breakage? (A). Early, (B). Late why? \_\_\_\_\_
51. Do you think the efficiency/capacity of millers affect rice recovery rate while milling? (A). Yes, (B). No

### **Focus-group discussion check list for processors.**

1. Do you have a milling machine? (A). Yes, (B). No
2. When do you start rice milling? (A). 1-3 years, (B). 3-6 years, (C). 6-9 years (D). 9-12 years (E). >12 years
3. What kind of rice milling machine do you have? (A). SB30. (B). N70, (C). Both
4. Do you think there is a loss while milling? (A). Yes, (B). No, if yes, please mention in detail?  
\_\_\_\_\_
5. What are the causes of losses? (A). \_\_\_\_\_ (B). \_\_\_\_\_ (C). \_\_\_\_\_ (D). \_\_\_\_\_ (E). \_\_\_\_\_
6. Please guess the amount of loss during milling per quintal? \_\_\_\_\_ kg
7. For how long do you store the rice? Paddy \_\_\_\_\_ days, milled \_\_\_\_\_ days average.
8. Do you think the loss rate is increased with increasing storage period? (A). Yes, (B). No
9. Which machine has better recovery rate? (A). SB type, (B). N type why?  
\_\_\_\_\_
10. What proportion (%) of the produce is milled by SB type (two- pass) 30?  
\_\_\_\_\_
11. What proportion (%) of the produce is milled by N type (one-pass)?  
\_\_\_\_\_
12. Which milling machine is used for processing of rice for marketing purpose? (A). SB30, (B). N70, why?  
\_\_\_\_\_

13. When do you observe the highest loss of rice and breakage occurred, can you mention the situation? 1. \_\_\_\_\_
14. Do you think the efficiency of millers affect rice recovery rate while milling? (A). Yes, (B). No, can you explain it? \_\_\_\_\_



## **Appendix 2: Glossary (explanation of key words in the document)**

**Bran:** The outer covering of the rice kernel after the husk is removed. It is removed during

**Broken:** pieces of the rice kernel that are less than 75% the size of the full kernel.

**Brown rice:** Dehusked paddy, often referred to as cargo rice or unpolished rice.

**Degree of milling:** Expression used to indicate the amount of bran removed in the milling process

**Dehusking:** The process of removing the husk from the paddy during milling.

**Enjera:** is the cultural food for Ethiopians, baked in a thin layer after the flour is mixed with water and fermented (2-3) days

**Gotta:** is a local grain storage material prepared from mud and straw

**Gottera:** is a local grain storage material made from bamboo, mud and straw

**Head rice:** The kernels of milled rice which are 75% kernel size or larger.

**Hull or husk:** Outer covering of the paddy grain.

**Husking or dehusking:** The process of removing the husk from the paddy grain during milling

**Milled rice:** Rice obtained from paddy after the husk and bran have been removed.

**Milling:** A general term representing the process of converting paddy into rice.

**One-pass milling:** is a machine that abrasive (remove) the bran and husk layers at a time

**Paddy:** The rice kernel with the husk on it, sometimes referred to as rough rice.

**Parboiling;** Hydrothermal treatment of paddy before milling. Includes soaking, treating with heat, and drying.

**PICS bag (Purdue improved grain storage):** is an improved airtight bag that prevents the grains from storage pests like weevil and preserve grain safely.

**Raw rice:** Rice that is not parboiled.

**Soaking:** Allowing paddy to remain in water to increase its moisture content during the parboiling process.

**Steaming:** In parboiling, subjecting the soaked paddy, to heat treatment by passing steam through the paddy mass to gelatinize the raw rice.

**Two-pass milling:** is a Rubber roll machine that removes the husk in the first stage and bran in the next stage separately.

**White rice:** a rice both husk and brand layers are removed wholly.

**Whole grain:** Head rice. A full kernel or piece of kernel that is 75% size or larger.

### Appendix 3: field data collected

Table 1: Harvesting loss data collected from harvested fields.

N O	name of farmer s	samples taken	Yield in Gram	loss weight in Gram	harvest ing MC 1 AV	sample yield MC 2 AV	loss sample MC 3 AV	% of loss
1	Teferi	sample 1	5203	299.43		14.9	13.7	5.75
		sample 2	6998	223.11		14	13.7	3.19
		sample 3	5994	191		13.4	13.1	3.19
		average MC/weight/t otal	<b>18195</b>	<b>713.54</b>	<b>17.3</b>	<b>14.1</b>	<b>13.5</b>	3.92
		Average loss						
2	Ambaw	sample 1	10297	281.73		17.2	14.2	2.74
		sample 2	11302	395.35		18	13.4	3.50
		sample 3	10878	234.51		17.3	13.2	2.16
		average MC/weight/t otal	<b>32477</b>	<b>911.59</b>	<b>21.2</b>	<b>17.5</b>	<b>13.6</b>	2.81
		Average loss						
3	Azeze	sample 1	6901	307.41		16.7	12.8	4.45
		sample 2	6895	135		15.7	12.9	1.96
		sample 3	5701	161.55		15.1	12.1	2.83
		average MC/weight/t otal	<b>19497</b>	<b>603.96</b>	<b>19.7</b>	<b>15.8</b>	<b>12.6</b>	3.10
		Average loss						
4	Alealign	sample 1	5330	115.24		11.7	11.5	2.16
		sample 2	6141	137.44		11.5	11.2	2.24
		sample 3	6938	139.23		14	11.3	2.01
		average MC/weight/t otal	<b>18409</b>	<b>391.91</b>	<b>16</b>	<b>12.4</b>	<b>11.3</b>	2.13
		Average loss						
5	Gedamu	sample 1	5920	227.84		24.1	14.3	3.85
		sample 2	7732	197.21		23.5	13.6	2.55
		sample 3	8350	291.55		25.2	14.1	3.49
		average weight	<b>22002</b>	<b>716.6</b>	<b>23</b>	<b>24.3</b>	<b>14</b>	3.26
		Average loss						

Table. 2: Threshing loss data collected from threshing fields.

N o	name of farmers	total yield Wt in KG	yield moisture	loss Wt in kg	percentage of threshing loss
1	Alelign	408	LM=10.74	23.86	5.85
2	Teferi	723.5	LM=11.01	25.59	3.54
3	Ambaw	1271.65	LM=11.6	40.11	3.2
4	Gedamu	1001.63	LM=12.43	27.83	2.78
5	Azeze	853.96	LM=11.5	32.66	3.82
					19.19
	<b>average threshing loss</b>				<b>3.838</b>
LM=loss moisture, Wt=is weight					

Table. 3: Drying and cleaning loss data

No	code/treatment	initial weight	final weight	loss weight	% of loss	remark
1	CL&Dy	25000	24500	297.16	1.18864	
2	CL&DY	25000	24700	263.67	1.05468	
3	CL&DY	25000	24500	271.55	1.0862	
	total weight	75000	73700	832.38	3.32952	
	loss average				1.10984	
	where: CL is cleaning and DY is drying					

Table. 4: milling result of different machines, products, head rice and millers comparison

milling result of different machine and product							
N o	replication	samples	intial Wt	final Wt	bran Wt	%ge grain recovery	remark
1	One-pass (raw paddy)	MK1	25	17.4	7	69.6	12.20%
		MK2	25	16.2	7.5	64.8	12.20%
		MK3	25	16.6	7.4	66.4	12.20%
		total Wt	75	50.2	21.9	66.93	
2	two-pass (raw paddy)	S1	25	19.2	3.5	76.8	12.20%
		S2	25	19.2	3.5	76.8	12.20%
		S3	25	19.2	3.4	76.8	12.20%
		total Wt	75	57.6	10.4	76.8	
3	two-pass (parboiled)	S1	25	20.1	3	80.4	
		S2	25	20	3.1	80	
		S3	25	20	3	80	
		total Wt	75	60.1	9.1	80.13	
comparisons of two different millers							
N o	replication	samples	initial Wt	final Wt after mill	bran Wt	%ge grain recovery	remark
1	miller 1	R1	25	17.4	7	69.6	12.20%
		R2	25	16.2	7.5	64.8	12.20%
		R3	25	16.6	7.4	66.4	12.20%

		<b>total Wt</b>	<b>75</b>	<b>50.2</b>	<b>21.9</b>	<b>66.93</b>	
2	millers	R1	25	17.2	6.8	68.8	12.20%
		R2	25	17.2	6.8	68.8	12.20%
		R3	25	17.2	6.7	68.8	12.20%
		<b>total Wt</b>	<b>75</b>	<b>51.6</b>	<b>20.3</b>	<b>68.8</b>	
<b>Head rice count result</b>							
N o	samples	machine	initial wt	head rice (gm)	broken rice (Gm)	head rice %	broken rice %
1	M1-polished	N70	10	5.25	4.75	52.5	47.5
2	M2-polished	N70	10	4.58	5.42	45.8	54.2
3	De-hulling raw	SB30	10	9.59	0.41	95.9	4.1
4	De-hulling parboiled	SB30	10	9.78	0.22	97.8	2.2
Where: M1 is miller one and M2 is miller 2							

Table. 5: storage loss data

N o	storage material	sampl es	Initial Wt (kg)	Initial moistur e (%)	Mid Wt (kg)	final Wt (kg)	final Wt in (kg)	Reco very (kg)	Recov ery rate (%)	Final moist ure (%)
1	Local (R2)	T1	25	12.9	24.9	24.7				
		T2	25	12.9	24.8	24.6				
		T3	25	12.9	24.9	24.7	74	51.6	69.73	12.44
2	PICS bag (R3)	T1	25	12.9	25	25				
		T2	25	12.9	25	25				
		T3	25	12.9	25	25	75	52.5	70	12.9
3	PPB (R1)	T1	25	12.9	24.5	24.2				
		T2	25	12.9	24.4	23.9				
		T3	25	12.9	24.8	24.3	72.7	49.5	68.1	10.98

Where: Wt is weight, R is replication, PPB is poly propylene bag

#### Appendix 4: rice production growth in Fogera district.

Table. 5: rice production profile of Fogera district since 2006-2007

N o	Production year	Area cultivated	Productivity/ ha	Total production	Participated household		
					Male	Female	Total
1	2007	8014	29.6	237,214	NA	NA	NA
2	2008	9231	45.3	418,164	”	”	”
3	2009	11085	59.9	663,991	”	”	”
4	2010	11146	59.9	667,645	”	”	”
5	2011	14149	47.5	672,077	”	”	”
6	2012	18429	61.7	1,377,069	”	”	”
7	2013	16071	72.6	1,166,754	”	”	”
8	2014	19310	82.2	1,587,282	24,649	1,599	26,248
9	2015	19333	77.9	1,506,040	27,835	2,077	29,912
10	2016	20896	74.1	1,548,393	29,761	723	30,484
11	2017	21341	75.5	1,611,245	35,616	931	36,547

Source: Fogera office of agriculture: where, NA is not available

#### Appendix 5: Fogera District 2016 rain feed production season crop coverage and productivity.

Table. 6: Cultivated crops with their corresponding area and production

No	Crop type	Cultivated land in ha	productivity	Total production
1	Maize	12,576	44.76	562,928
2	Finger millet	10,846	24.89	270,002
3	Potato	954	155.14	148000
4	Rice	21,341	75.5	1,611,245
5	Groundnut	501	26.51	13,283
6	Barley	3,582	22.00	78,804
7	Niger seed	1,145	8.11	9,286
8	Bean	985	18.36	18,081
9	Teff	5,692	21.39	121,788
10	Line seed	22	6.00	132
11	Pea	19	14.00	266
12	Wheat	36	30.00	1,080
13	Pepper	1,529	13.16	20,120
14	Sorghum	11	20.00	220
15	Tomato	20	300.00	6,000
16	Garlic	13	90.00	1,170
17	Onion	15	200.00	3,000
18	Vetch	103	20.00	2,060
	Total	59390		2,906,844



## Appendix 6: photos



Fig. 1: Harvesting of rice samples



Fig. 2: Threshing of rice samples

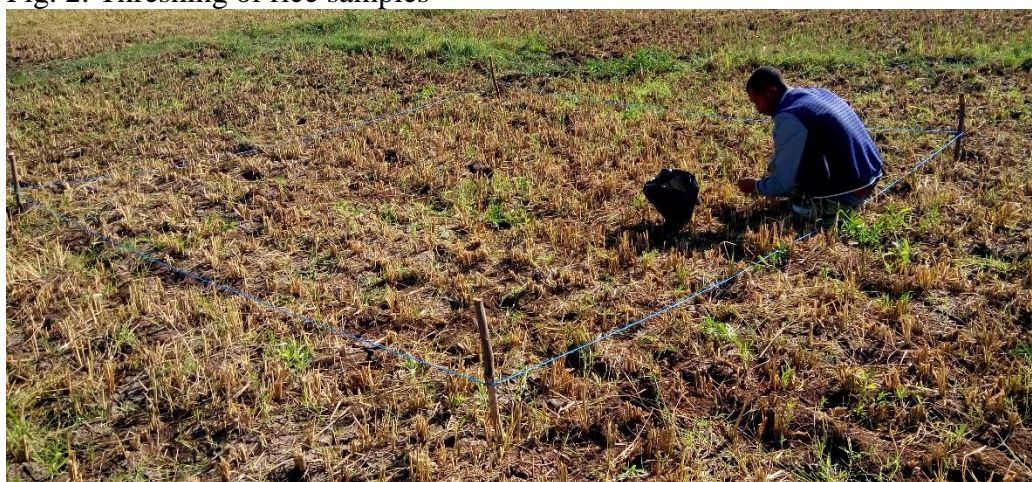


Fig. 3: Harvesting loss collection.





Fig. 4: Threshing loss data collection



Fig. 5: Farm gate storage loss trials.



Fig. 6: Cleaning and drying loss trial





Fig. 7: Milling loss trials



Fig. 8: Two-pass and one-pass rice milling machines from left to right.



Fig. 9: Electric powered parboiling material for paddy rice





Fig. 10: Oxen threshing.



Fig. 11: Stick threshing by women.



Fig. 12: Bundling of the straw for undetached grain collection.





Fig. 13: Local grain storage silo.



Fig. 14: PICS bag internal and external look from left to right.



Fig. 15: Digital moisture meter and spring balance used during the field work